BIOCCUS: BIOMASS COGENERATION WITH CARBON CAPTURE

Air Quality Assessment Report

Report for: Ricardo A&I

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Executive Summary

A pilot BIOCCUS (bioenergy with carbon capture and utilization or storage) project is proposed at Holmstead Farm, Staplefield Road, Cuckfield, Haywards Heath, RH17 5J, hereafter referred to as the Facility. The concept is designed with the aim of maximising negative emission potential, combining two established GGR concepts, namely biochar and BECCS. BIOCCUS is a biomass pyrolysis-based cogeneration system with biochar production and CO_2 capture, utilisation and permanent storage. The technology uses undried and un-processed waste wood (i.e., not pelleted) from sustainably-sourced domestic timber to produce electricity and heat in addition to biochar and commercial grade carbon dioxide. The facility will operate for 8000 hours a year, consume 1400 kg/hr of biomass @50% moisture and will have a thermal input of 1.3 MW, an electrical output of 138.4 kWe and heat output of 872 kWth.

This Facility would be regulated by the Environment Agency as a Part B installation under Schedule 1, Part 2, Section 5.1 Part B (a) (v) with a permit that only regulates emissions to air. In order for permit to be granted, an air quality assessment of the impact of emissions associated with the Facility has been undertaken.

A review of the surrounding area has shown that the Facility is located in an area designated as a statutory Area of Outstanding Natural Beauty (AONB). There are several Sites of Special Scientific Interest (SSSIs) and Local Nature Reserves (LNRs) designated for sensitive ecological species within 10km of the Facility. The closest are Cow Wood and Harrys SSSI (approximately 3.1 km away) and Blunts and Paiges Wood LNR (approximately 3.7 km away). There are unlikely to be any significant air quality impacts at the SSSI and LNRs as this fall outside the Environment Agency (EA) risk assessment guidance screening distance of 2 km.

There are no Special Protection Area (SPA), Special Areas of Conservation (SAC) and Ramsar designated sites within EA guidance screening distance of 10km from the Facility. As such, no further consideration of air quality impacts on ecologically designated sites is required in this assessment.

However, there are several nearby human receptors close to the Facility, as such the air quality impacts assessment has considered the impact of emissions from the Facility at these nearby human receptors.

The Facility is located in Mid Sussex District Council (MSDC). Air quality in generally good in MSDC, however a very small Air Quality Management Area (AQMA) has been declared covering three properties at a junction of Stone Pound Crossroads due to traffic emissions. This AQMA is over 11 km away from the Facility as such, no air quality impacts are likely within the AQMA due to the operation of the Facility.

The pollutants relevant to this air quality assessment includes the pollutants attracting an emission limit according to the attached Environmental permitting technical guidance PG5/1(21) and pollutants emitted as the result of amine-based carbon capture process, including ammonia, amines and their degradation products (e.g. nitrosamines).

The assessment has used the dispersion model ADMS to predict the increases in pollutant species released as a result of the emissions released during the operation of the Facility, using best practice approaches. The assessment has been undertaken based on several worse case assumptions including assuming that the facility would operate at the emissions limits, albeit this unlikely as it is only a small pilot project.

The results of dispersion modelling indicate that Process Contributions and resultant Predicted Environmental Concentrations of all pollutants at human receptors are of negligible significance, except for benzene and nitrogen dioxide with a minor to moderate significance. However, this occurs at only four receptors out of the 41 receptors. Furthermore, the predicted environmental concentration at these receptors is well below (less than 70%) the relevant air quality standards.

Given that several worse case assumptions have been adopted, it is expected that overall, the effects of the proposed Facility are likely to be of negligible significance

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1. INTRODUCTION

1.1 BACKGROUND

This report details the air quality impacts associated with the pilot BIOCCUS (bioenergy with carbon capture and utilization or storage) project proposed at Holmstead Farm, Staplefield Road, Cuckfield, Haywards Heath, RH17 5JF, thereafter referred to as the Facility. Figure 1.1 shows the location of the Facility.

The BIOCCUS concept is designed with the aim of maximising negative emission potential, combining two established GGR concepts, namely biochar and BECCS. BIOCCUS is a biomass pyrolysis-based cogeneration system with biochar production and CO_2 capture, utilisation and permanent storage. The technology uses undried and un-processed waste wood (i.e., not pelleted) from sustainably-sourced domestic timber to produce electricity and heat in addition to biochar and commercial grade carbon dioxide. The facility will operate for 8000 hours a year, consume 1400 kg/hr of biomass @50% moisture and will have a thermal input of 1.3 MW, an electrical output of 138.4 kWe and heat output of 872 kWth. The amine carbon capture system can be fully bypassed and will be operated for a theoretical maximum of 4,000 hours a year; in practice, we do not expect the operating hours for the carbon capture system to exceed 2,000 hours a year.

Consultation with the relevant regulatory authority (the Environment Agency) has confirmed in their letter dated 24 May 2022 that the activity will be regulated as a Part B installation under Schedule 1, Part 2, Section 5.1 Part B (a) (v) with a permit that only regulates emissions to air. The letter also states the following:

"MCP that is a 1.1 Part B or a 5.1 Part B activity - Air quality assessment required for both human health and ecological receptors, if present, using H1. Detailed air dispersion modelling will be required if H1 does not screen out emissions.

Where an air quality assessment is required, you should submit your assessment, the H1 screening tool with your application. Where detailed air dispersion modelling is required, you should submit your modelling report and the model input files with your application.

….

Pollutants to be considered in the air quality assessment:

- ***All the pollutants attracting an emission limit according to the attached Environmental permitting technical guidance PG5/1(21)***
- ***All the emitted pollutants with a potential to cause acidification or nutrient nitrogen deposition to habitat sites.***
- ***All the pollutants emitted as the result of amine-based carbon capture process, including ammonia, amines and their degradation products (e.g. nitrosamines)***

Refer to AQMAU recommendations for the assessment and regulation of impacts to air quality from amine-based post-combustion carbon capture plants report for advice on air emissions risk assessment of emissions of amines and their degradation products from post-combustion carbon capture plants. As part of the air emissions risk assessment, we will likely need information on how the composition of the amine-based solvent determines its emission profile, including emissions of amine degradation products."

The Facility is located in Mid Sussex District Council (MSDC). Air quality in generally good in MSDC, however a very small Air Quality Management Area (AQMA) has been declared covering three properties at a junction of Stone Pound Crossroads due to traffic emissions. This AQMA is over 11 km away from the Facility as such, no air quality impacts are likely within the AQMA due to the operation of the Facility.

During the operational phase, the principal source of atmospheric emissions from the Facility will be residual levels of pollutants exhausted from the stack after treatment in the flue gas cleaning system. In line with the requirements of the EA, a detailed atmospheric dispersion modelling has been undertaken to predict the effects of the operation of the Facility on ground level pollutant concentrations at nearby human receptors within 10 km.

Other potential sources of emissions are vehicles accessing the site and construction dust which have not been reviewed at this stage but will be considered in the planning application.

1.2 EMISSIONS TO AIR

The relevant pollutants considered within this air quality impact assessment are as follows:

- Pollutants with emissions limits applicable to the Facility as stated in Environmental permitting technical guidance PG5/1(21) are listed below:
  - Carbon monoxide (CO)
  - Particulate matter (dust)
  - Nitrogen Oxides (NOx)
  - Total Volatile Organic Compounds (TVOC)[1]
  - Hydrogen Cyanide[2]
  - Formaldehyde
- Pollutants specific to the carbon capture activity of the Facility are:
  - Ammonia
  - Amines
  - Nitramines
  - Nitrosamines
  - Acetaldehyde

No further consideration has been given to any of the pollutants with a potential to cause acidification or nutrient nitrogen deposition to habitat sites, as there are no sensitive habitats within the relevant EA screening distance. The air quality impacts of the aforementioned pollutants on human receptors have therefore been considered in this report.

1.3 RELEVANT GUIDANCE

This impact assessment has been undertaken in accordance with the following guidance documents:

- Defra, 2022, Local Air Quality Management - Technical Guidance LAQM.TG(22);
- Environment Agency guidance on environmental permitting: air dispersion modelling reports. Available at https://www.gov.uk/guidance/environmental-permitting-air-dispersion-modelling-reports
- Environment Agency guidance on air emissions risk assessment. Available at https://www.gov.uk/guidance/air-emissions-risk-assessment-for-your-environmental-permit
- Institute of Air Quality Management (IAQM), 2017, Land-use Planning and Development Control: Planning for Air Quality.

[1] TVOC is assumed to be benzene
[2] Only applicable when melamine faced woods are in the fuel

2. AIR QUALITY STANDARDS

2.1 AIR QUALITY OBJECTIVES

The Air Quality Strategy (AQS) for England, Scotland, Wales and Northern Ireland (Defra, 2007) sets out UK policy on air quality including a framework for reducing hazards to health from air pollution and meeting international commitments. It sets standards and objectives for ten main air pollutants (including nitrogen dioxide, PM_{10} and $PM_{2.5}$) to protect health, vegetation and ecosystems. The European Union has also set limit values for nitrogen dioxide, PM_{10} and $PM_{2.5}$ (EU Directive 2008/50/EC) and is implemented in UK law through the Air Quality Standards Regulations (2010). The limit values for nitrogen dioxide, PM_{10} and $PM_{2.5}$ are the same numerical concentrations as the UK objectives.

The AQO which are relevant to this air quality impact assessment are detailed in Table 2-1.

Table 2-1: National Air Quality Objectives (AQOs)

Pollutant	Measured As	Objective
Nitrogen dioxide (NO_2)	Annual mean	40 µg/m^3
	1-hour mean	200 µg/m^3 not to be exceeded more than 18 times a year
Particles (PM_{10})	Annual mean	40 µg/m^3
	24-hour mean	50 µg/m^3 not be exceeded more than 35 times a year
Fine particles ($PM_{2.5}$)	Annual mean	25 µg/m^3 (World Health Organisation (WHO) guideline 10µg/m^3)
Carbon Monoxide	Maximum daily running 8 hour mean	10,000 µg/m^3
Benzene (a)	Annual mean	5 µg/m^3
	Running annual mean	16.25 µg/m^3

Note: (a) Assumed to be representative of TVOC

LAQM.TG(22) sets out that the annual mean AQOs for human health apply at locations where the public may be regularly exposed, such as building facades of residential properties, schools, hospitals and care homes. The 1-hour and 24-hour mean AQOs apply at locations where it is reasonable to expect members of the public to spend at least these periods of time, such as busy shopping streets and school playgrounds for the 1-hour mean, and hotels or residential gardens for the 24-hour mean.

2.2 ENVIRONMENTAL ASSESSMENT LEVELS

There are some pollutants in the Environmental permitting technical guidance PG5/1(21) relevant to this Facility which do not have statutory air quality standards prescribed under current legislation. For these pollutants, a number of non-statutory air quality objectives and guidelines exist including the EA guidance on air emissions risk assessment provides further assessment criteria in the form of Environmental Assessment Levels (EALs).

The EALs which are relevant to this air quality impact assessment are detailed in Table 2-2.

Table 2-2: Environmental Assessment Levels (EALs)

Pollutant	Measured As	Objective
Hydrogen Cyanide	1 hour mean	220 µg/m^3
Formaldehyde	30-minute mean	100 µg/m^3

Pollutant	Measured As	Objective
	Annual mean	5 µg/m^3
Acetaldehyde	1 hour mean	9,200 µg/m^3
	Annual mean	370 µg/m^3
Ammonia	1 hour mean	180 µg/m^3
	Annual mean	2,500 µg/m^3
Benzene	24 hour mean	30 µg/m^3
Carbon Monoxide	1 hour mean	30,000 µg/m^3
N-nitrosodimethylamine (NDMA) [(a)]	Annual mean	0.0002 µg/m^3

MDEA and piperazine concentrations were assessed against derived EALs. These derived EALs are presented in Table 2-3. Details of the derivation of these EALs and the model setup for amine emissions are provided in Appendix A.

Table 2-3: Derived Environmental Assessment Levels (EALs) for amines

Pollutant	Measured As	Objective
MDEA	1 hour mean	400 µg/m^3
	24 hour mean	100 µg/m^3
Piperazine	15-minute mean	1 µg/m^3
	8-hour mean	30 µg/m^3

2.3 SIGNIFICANCE CRITERIA

According to H1 screening approach, the Process Contribution (PC) from the facility must meet both of the following criteria to be screened out:

- the short-term PC is less than 10% of the short-term environmental standard; and
- the long-term PC is less than 1% of the long-term environmental standard

Where the PC is not screened out, then the following criteria can be applied:

- the short-term PC should be less than 20% of the short-term environmental standards minus twice the long term background concentration; and
- the long-term PEC should be less than 70% of the long-term environmental standards.

Where the PCs and PECs cannot be screened out using the H1 screening approach, the significance of the air quality impact of the Facility on the nearby human health receptors has been determined using the approach described in the IAQM planning guidance, which sets out descriptors for evaluating the significance of predicted changes in annual average concentrations at individual human health receptor locations.

Table 2-4: Impact Descriptors for Individual Receptors

Long-term average concentration at receptor in assessment year	**% Change in Concentration relative to Air Quality Objective (AQO)**			
	1%	**2 – 5%**	**6 – 10%**	**>10%**
75% or less of AQO	Negligible	Negligible	Minor	Moderate
76 – 94% of AQO	Negligible	Minor	Moderate	Moderate
95 – 102% of AQO	Minor	Moderate	Moderate	Major

Long-term average concentration at receptor in assessment year	% Change in Concentration relative to Air Quality Objective (AQO)			
103 – 109% of AQO	Moderate	Moderate	Major	Major
110% or more of AQO	Moderate	Major	Major	Major

The guidance states that percentage changes in concentration, relative to the AQO, of less than 1%, but greater than or equal to 0.5%, should be rounded up to 1%. Changes of less than 0.5% are described as 'negligible'. Although Table 2-4, applies only to long-term concentrations, it has also been used to determine the significance of short-term concentrations for a conservative assessment.

The overall significance of the Facility is determined by professional judgement, taking into account the significance at individual receptors and other factors such as the number of people or properties that will be exposed to a change in air quality.

3. DISPERSION MODELLING METHODOLOGY

3.1 SCOPE OF THE ASSESSMENT

The approach to the assessment of emissions from the proposed Facility includes the following key elements:

- Establishing the background Ambient Concentration (AC) from consideration of existing local air quality through a review of available air quality monitoring data available from several networks and the Defra background mapping projections in the vicinity of the Facility. A review of the background is provided in Chapter 4.
- Quantitative assessment of the operational impacts on local air quality from pollutants emitted from the Facility utilising a “new generation” Gaussian dispersion model, ADMS 5.2.
- Assessment of Process Contributions (PC) from the Facility in isolation, and assessment of resultant Predicted Environmental Concentrations (PEC) taking into account cumulative impacts through incorporation of the AC; and
- Determining the significance of the impact on human receptors using the EA and IAQM significance criteria.

3.2 DISPERSION MODEL

A number of commercially available dispersion models are able to predict ground level concentrations arising from emissions to atmosphere from elevated point sources. Modelling for this study has been undertaken using the latest version of ADMS (ADMS 5.2), developed by Cambridge Environmental Research Consultants (CERC).

ADMS 5 is a new generation Gaussian plume air dispersion model. The model calculates the mean concentration over flat terrain and also allows for the effect of plume rise, complex terrain, buildings, radioactive decay and deposition.

Dispersion models predict atmospheric concentrations within a set level of confidence and there can be some variations in results between models under certain conditions; the ADMS 5.2 model has been formally validated and is widely used in the UK and internationally for regulatory purposes.

ADMS comprises a number of individual modules each representing one of the processes contributing to dispersion or an aspect of data input and output. Amongst the features of ADMS are:

- An up-to-date dispersion model in which the boundary layer structure is characterised by the height of the boundary layer and the Monin-Obukhov length, a length scale dependent on the friction velocity and the heat flux at the surface. This approach allows the vertical structure of the boundary layer, and hence concentrations, to be calculated more accurately than does the use of Pasquill-Gifford stability categories, which have been used in many previous models (e.g. ISCST3). The restriction implied by the Pasquill-Gifford approach that the dispersion parameters are independent of height is avoided. In ADMS the concentration distribution is Gaussian in stable and neutral conditions, but the vertical distribution is non-Gaussian in convective conditions, to take account of the skewed structure of the vertical component of turbulence.
- A number of complex modules including the effects of plume rise, complex terrain, coastlines, concentration fluctuations, amine chemistry and buildings.
- A facility to calculate long-term averages of hourly mean concentration, dry and wet deposition fluxes and radioactivity, and percentiles of hourly mean concentrations, from either statistical meteorological data or hourly average data.

The ADMS input parameters used for this project is described below and further details of the input data used for the amine degradation assessment is provided in Appendix 1.

3.3 METEOROLOGICAL DATA

The most important meteorological parameters governing the atmospheric dispersion of pollutants are wind direction, wind speed and atmospheric stability as described below:

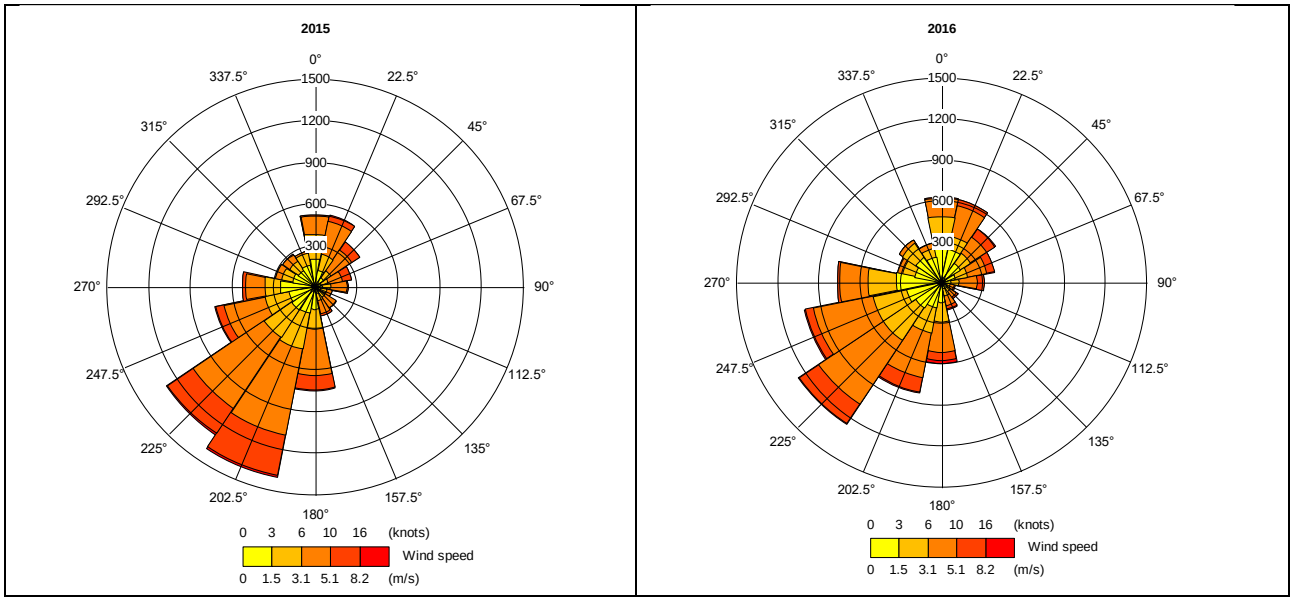
- Wind direction determines the sector of the compass into which the plume is dispersed.
- Wind speed affects the distance that the plume travels over time and can affect plume dispersion by increasing the initial dilution of pollutants and inhibiting plume rise.
- Atmospheric stability is a measure of the turbulence of the air, and particularly of its vertical motion. It therefore affects the spread of the plume as it travels away from the source. New generation dispersion models, including ADMS, use a parameter known as the Monin-Obukhov length that, together with the wind speed, describes the stability of the atmosphere.

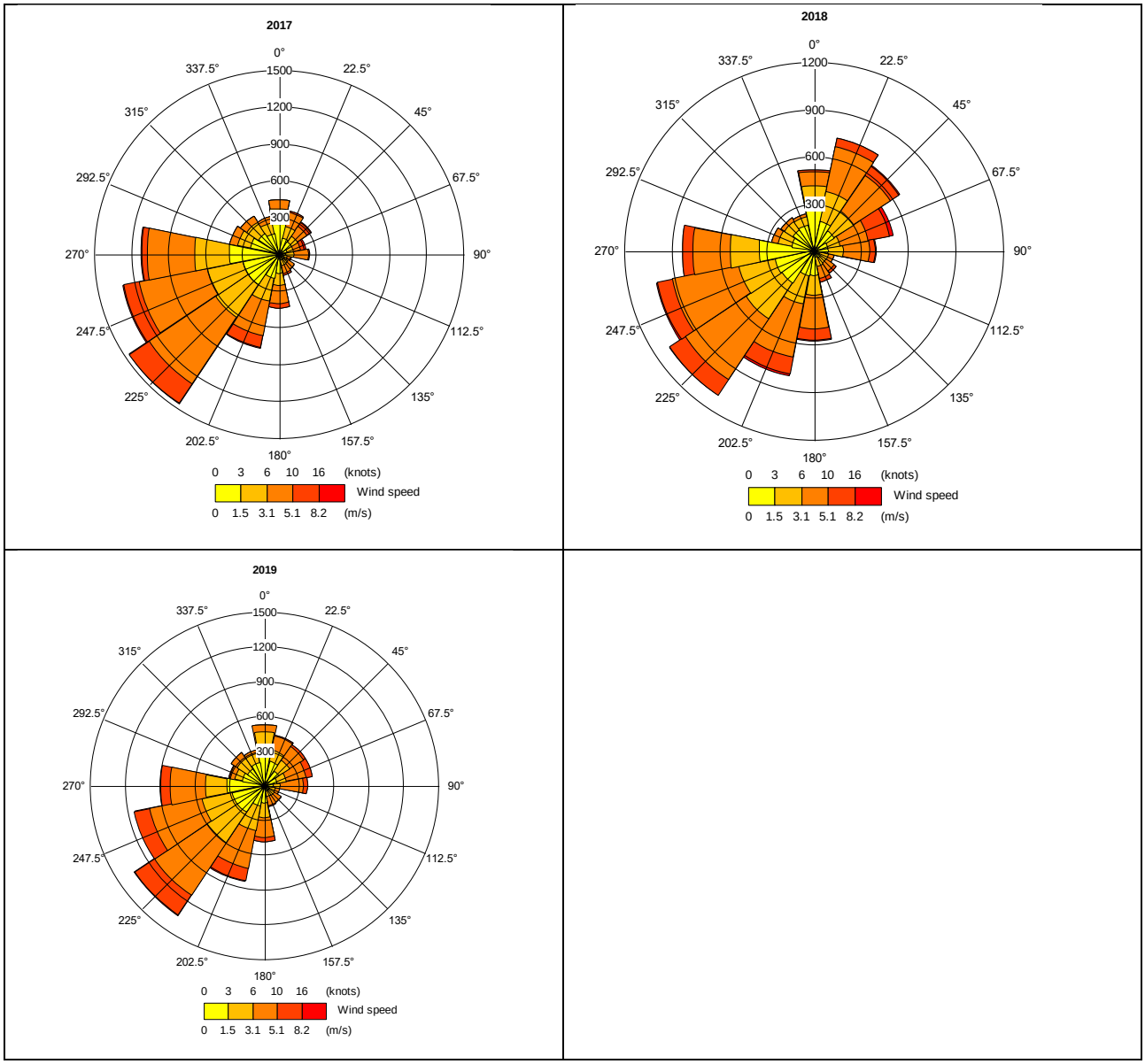
For meteorological data to be suitable for dispersion modelling purposes, a number of meteorological parameters need to be measured on an hourly basis. These parameters include wind speed, wind direction, cloud cover and temperature. There are only a limited number of sites where the required meteorological measurements are made.

The year of meteorological data that is used for a modelling assessment can have a significant effect on source contribution concentrations. Dispersion model simulations were performed for emissions from the proposed Facility using five years of data from Charlwood meteorological station (approximately xx km to the xxx of the Facility) between 2015 and 2019.

Figure 3-1 shows the wind roses for each of the years of meteorological data used in this assessment.

Figure 3-1: Windrose for Charlwood meteorological station, 2015 to 2019





3.4 TERRAIN

The presence of elevated terrain can significantly affect (usually increase) ground level concentrations of pollutants emitted from elevated sources such as stacks, by reducing the distance between the plume centre line and ground level and increasing turbulence and, hence, plume mixing. The area surrounding the Facility has a gradient of less than 10%, as such terrain data has not been included. However, a sensitivity test has been undertaken using terrain data and the results show that there are no significant differences with or without terrain data.

3.5 SURFACE ROUGHNESS

The roughness of the terrain over which a plume passes can have a significant effect on dispersion by altering the velocity profile with height, and the degree of atmospheric turbulence. This is accounted for by a parameter called the surface roughness length.

A surface roughness length of 0.2 m has been assigned during the meteorological processing in ADMS 5.2, to represent the low agricultural surface characteristics across the study area.

3.6 BUILDING WAKE EFFECTS

The movement of air over and around buildings generates areas of flow circulation, which can lead to increased ground level concentrations in the building wakes. Where building heights are greater than about 30 - 40% of the stack height, downwash effects can be significant. The dominant structure (i.e., with the greatest dimensions likely to promote turbulence) is the Main Building which the stack is attached to. The dimensions of the buildings included within the model are listed in Table 3-1.

Table 3-1: Dimensions of Buildings Included Within the Dispersion Model

X,Y (m) Reference of Building Centre	Height (m)	Length/Width or Diameter (m)	Angle (°) From North
528222,126377	**10.5**	**25 by 32**	**345**
528203,126395	10.5*	17 by 46	345
528163,126368	10.5*	56 by 30	345
528175,126423	10.5*	50 by 27	345
528252,126429	10.5*	61 by 30	345
528203,126429	10.5*	37 by 30	345

Note: **Bold** – Main Building, * - height used in model but actual height is lower.

3.7 EMISSION PARAMETERS AND RATES

The Facility stack location has been modelled at national grid reference coordinates 528237,126381. The stack emission characteristics are summarised in Table 3-2 and are based on the flue gas specification when 35% flue gas recirculation (FGR) is in use. Stack emission characteristics for a scenario where no FGR is in use are also provided; sensitivity testing demonstrated that the "with FGR" case is worst-case for pollutant concentrations near the site, so these parameters were used for the full modelling.

Table 3-2: Stack Emission Characteristics

Parameter	Unit	FGR	No FGR
Stack Height (a)	m	10.6	
Number of flues	-	1	
Effective diameter	m	0.3	
Efflux velocity	m/s	9	13.6
Efflux temperature	°C	60	60
Oxygen content	% (wet basis)	8.1	12.3
H_2O content	%	13.6	9.1
Volumetric flow	Nm^3/h (O^0C, dry, 6% O_2)	1255	1277

The quantitative assessment includes consideration of the operation of the Facility assuming emissions from the stack are at the limits set in the technical guidance PG5/1(21) and other relevant documents. The modelling of emissions at 100% of the concentration limits therefore represents a worst-case scenario, as in reality, emissions from the Facility are expected to be considerably lower than these limits. Table 3-3 summarises the mass emission rates used in this assessment.

Table 3-3: Mass Emissions of Released Pollutants

Pollutants	Emission limit (mg/Nm^3) @ (O^0C, dry)	ELV Reference $\%O_2$	Mass Emission (g/s) FGR	Mass Emission (g/s) no FGR
Carbon monoxide	375[(a)]	6	0.131	0.133
Dust	90[(a)]	6	0.031	0.032
NOx	600[(a)]	6	0.209	0.213
TVOC	30[(a)]	6	0.010	0.011
HCN	7.5[(a)]	6	0.003	0.003
Formaldehyde	7.5[(a)]	6	0.003	0.003
Ammonia	3[(c)]	15	0.0026	0.0027
Acetaldehyde	5.3[(d)]	15	0.0047	0.0047
Nitrosamine	0.002[(e)]	15	1.760×10^{-6}	1.792×10^{-6}
MDEA and piperazine	20[(e)]	5	0.006533	0.006650
MDEA	-	5	0.005226	0.00532
Piperazine	-	5	0.001307	0.00133

Note:

(a) Derived from Table 5.3 of Environmental permitting technical guidance PG5/1(21), however this is a conservative emission limit compared to Table 5.4 which is applicable to the Facility.

(b) For Winnington CCUS project, the Environment Agency proposed a limit of 20 mg/m^3 for all amine products (as MEA).

(c) The licensors for this project have provided an emission concentration of 2.5ppm (1.74 mg/m^3). In order to provide a worst-case assessment of ammonia concentrations, we have used an emission value of 3 mg/m^3, which corresponds to the lower bound of the range of emissions estimates in BAT 7 of the Large Combustion Plants BREF: https://eippcb.jrc.ec.europa.eu/reference/large-combustion-plants-0.

(d) Process-specific concentrations are not available at this stage, so we have used the maximum emissions concentration provided by licensors at the Net Zero Teeside site, as reported in
Net Zero Teesside – Environmental Statement Appendix 8B: Air Quality - Operation Phase

e) Process-specific concentrations are not available at this stage, so we have used the maximum emissions concentration provided by licensors at other similar sites, including the Net Zero Teesside site:
Net Zero Teesside – Environmental Statement Appendix 8C: Air Quality Assessment of Amine Degradation Products
and
Keadby 3 Low Carbon Gas Power Station Project: Environmental Statement Volume II - Appendix 8C: Air Quality Assessment of Amine Degradation Products
The amine solvent to be used is 80% MDEA and 20% piperazine; total amine emissions have been apportioned on this basis.

3.8 MODELLED RECEPTORS

LAQM.TG(22) provides examples of where the air quality objectives should and should not apply. Sensitive receptors should be selected where the public may be regularly exposed, such as building facades of residential properties, schools, hospitals and care homes. The 1-hour and 24-hour mean AQOs apply at locations where it is reasonable to expect members of the public to spend at least these periods of time, such as busy shopping streets and school playgrounds for the 1-hour mean, and hotels or residential gardens for the 24-hour mean.

Modelling runs assumed a coarse grid with 250 m receptor spacing to a 10 km radius around the Facility development, 50 m spacing to a 2km radius around the Facility and a fine grid of 25 m spacing to a 500 m radius around the Facility. In addition, the operational effects of the proposed development have been

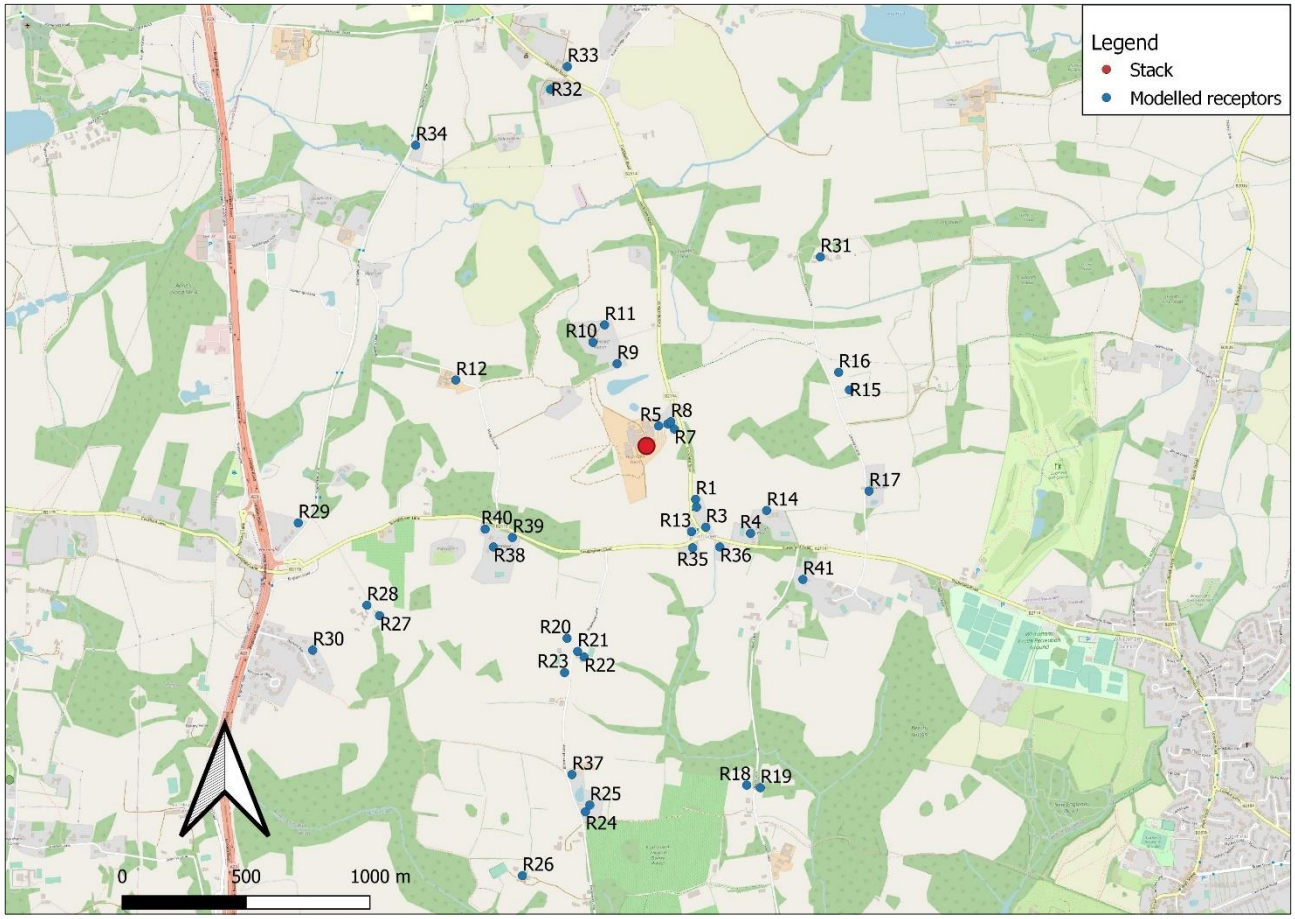
assessed at the façades of local existing receptors. 41 receptors have been selected at representative locations where changes in pollutant concentrations are anticipated to be greatest as a result of the proposed development. The receptor locations are provided in Table 3-4 and illustrated in Figure 3-2. All receptors have been modelled at a height of 1.5 m, representative of typical head height.

Table 3-4: Modelled Sensitive Receptors

Receptor ID	Receptor Location	Approximate OS Grid Reference (m) (X,Y)
R1	Cuckfield Road 4	528438, 126168
R2	Cuckfield Road 2	528438, 126132
R3	Cuckfield Road 22	528474, 126054
R4	Slough Place Farm	528660, 126030
R5	Holmstead Farm 1	528288, 126462
R6	Holmstead Farm Bunga	528324, 126468
R7	Holmstead Farm Bunga	528348, 126450
R8	Hollyhus	528336, 126480
R9	Holmsted Manor 1	528120, 126714
R10	Holmsted Manor 2	528024, 126798
R11	The Coach House	528066, 126870
R12	Mallion's Farm	527466, 126648
R13	Slough Green Cottage	528420, 126036
R14	Slough Place Cottage	528720, 126120
R15	Cleavers Barn	529056, 126606
R16	Cleavers Cottage	529014, 126678
R17	Mizbrooks House	529134, 126198
R18	Winscot	528642, 125016
R19	Oakfield House	528696, 125004
R20	Moorfields Farm Cott	527916, 125604
R21	Moorfields Farmhouse	527958, 125550
R22	Moorfields	527988, 125532
R23	Fowlers	527904, 125466
R24	Spencer Barn	527988, 124908
R25	Barsnape Farm	528006, 124932
R26	Broxmead Farm	527736, 124650
R27	Oak Wood House	527160, 125694
R28	Great Thorndean Farm	527106, 125736
R29	Little Domick	526830, 126072
R30	Wych Cottage	526890, 125556
R31	Bigges Farm 1	528942, 127140
R32	The Forge	527850, 127818

Receptor ID	Receptor Location	Approximate OS Grid Reference (m) (X,Y)
R33	Red House (Staplefield)	527916, 127908
R34	Amberstone	527304, 127596
R35	Slough Green House	528426, 125970
R36	Deaks Mead	528534, 125976
R37	Hazelbrook Farm	527934, 125058
R38	Barsnape Lodge	527622, 125976
R39	Barnsnape Lodge	527694, 126012
R40	Paternosters Cottage	527586, 126048
R41	Deaks	528870, 125844

Figure 3-2: Modelled Receptors

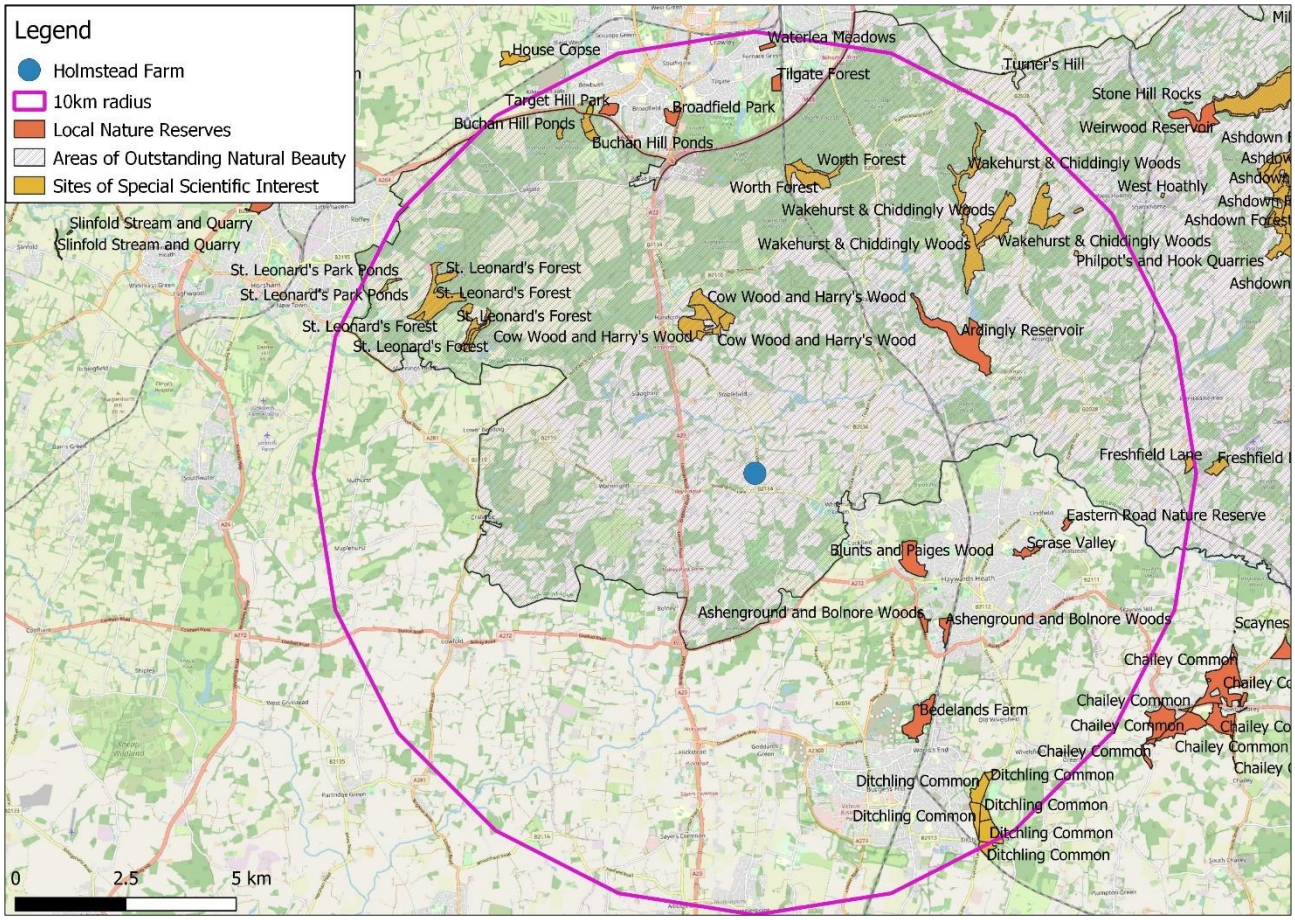


3.9 HABITAT SITES

The Facility is located in an area designated as a statutory Area of Outstanding Natural Beauty (AONB). There are several Sites of Special Scientific Interest (SSSIs) and Local Nature Reserves (LNRs) designated for sensitive ecological species within 10km of the Facility. The closest are Cow Wood and Harrys SSSI (approximately 3.1 km away) and Blunts and Paiges Wood LNR (approximately 3.7 km away). There are unlikely to be any significant air quality impacts at the SSSI and LNRs as this fall outside the Environment Agency (EA) risk assessment guidance screening distance of 2 km.

There are no Special Protection Area (SPA), Special Areas of Conservation (SAC) and Ramsar designated sites within EA guidance screening distance of 10km from the Facility. As such, no further consideration of air quality impacts on ecologically designated sites is required in this assessment.

Figure 3-3: Holmstead Farm and surrounding area



3.10 SENSITIVITY ANALYSIS OF DISPERSION MODEL INPUT PARAMETERS

In order to provide a quantitative assessment of model uncertainty, a series of sensitivity tests was carried out to assess the sensitivity of the model results into key input parameters, so as to ensure that the worst-case impacts have been considered. The parameters tested include:

- 5 years of meteorological data;
- Higher flow rate of 13.6 m/s, which is expected if no FGR is in place;
- The effect of terrain; and
- The effect of changes to the surface roughness to 0.1 m and 0.3 m.

Results of the sensitivity testing are provided in Appendix 2.

3.11 LIMITATIONS AND ASSUMPTIONS

3.11.1 Modelling assumptions and limitations

The greatest uncertainty associated with any dispersion modelling assessment arises through the inherent uncertainty of the dispersion modelling process itself. Nevertheless, the use of dispersion modelling is a widely applied and accepted approach for the prediction of impacts from industrial sources. In order to minimise the likelihood of under-estimating the PC to ground level concentrations from the main stack, the following conservative assumptions have been made within the assessment:

- Modelling assumes a continuous operation throughout the year for 8760 hours however on reality the facility will operate for 8,000 hours only. This provides an assessment of the 'worst case' operational emissions from the Facility;
- Emissions of pollutants from the Main Stack have been assumed to be at the ELVs, however in reality the Facility is expected to operate at much lower emissions;
- The emission limit which is applicable to dust has been assumed to be equivalent to PM_{10} and $PM_{2.5}$;
- The modelling predictions are based on the use of five full years of meteorological data from Charlwood meteorological station for the years 2015 to 2019 inclusive, with the highest result for the worst year being reported; This is considered to be conservative; and
- The nearby buildings have been included in the assessment assuming a similar height to the Main building.

3.11.2 NO_X to NO_2 assumptions

The NOx emissions associated with combustion activities at the proposed EfW facility will typically comprise approximately 90-95% nitric oxide (NO) and 5-10% nitrogen dioxide (NO_2) at source. The NO oxidises in the atmosphere in the presence of sunlight, ozone and volatile organic compounds to form NO_2, which is the principal concern in terms of environmental health effects.

There are various techniques available for estimating the proportion of NOx converted to NO_2. However, in line with the EA's recommendations for a 'worst case scenario', a 100% conversion of NO to NO_2 has been assumed for calculation of long-term concentrations, while a 50% conversion of NO to NO_2 is assumed for short-term NO_2 concentrations.

4. BASELINE AIR QUALITY

The Facility is located within Mid Sussex District Council administrative boundary. Air quality in generally good in MSDC, however a very small Air Quality Management Area (AQMA) has been declared covering three properties at a junction of Stone Pound Crossroads due to traffic emissions. This AQMA is over 11 km away from the Facility as such, no air quality impacts are likely within the AQMA due to the operation of the Facility.

Baseline conditions for air quality have been derived by reviewing available data from the following sources:

- Background mapping data (Defra, 2021) for local authorities;
- MSDC local monitoring data;
- Sussex Air Quality Network;
- Automatic Urban and Rural Network;
- Non automatic Hydrocarbon Network and Automatic Hydrocarbon Network;
- UKEAP: National Ammonia Network; and
- Other locally managed automatic monitoring.

Mapped data and monitored concentrations have been extracted for all the pollutants relevant to this assessment as listed in Section 1.2, except for hydrogen cyanide, formaldehyde, aldehyde, amines, nitrosamines and nitramines, as no background monitoring network exists for these in the UK.

4.1 DEFRA BACKGROUND AIR QUALITY MAPPING

Defra provides modelled background air quality concentrations for each 1x1 km grid across all local authority areas, from a base year of 2018 which is projected to provided data for all years up to 2030. Projections assume a year-on-year improvement in air quality concentrations due to improved vehicle fleet emissions. Table 4-1 presents the estimated background air quality concentrations for the 1x1 km grid square (528500,126500) encompassing the Facility for 2021.

Table 4-1: 2021 Defra background air quality concentrations (µg/m^3)

Pollutant	Concentration (µg/m^3)
NOx	10.79
NO_2	8.34
PM_{10}	13.47
$PM_{2.5}$	8.68

Comparing the background concentrations to the annual mean AQOs (as identified in Table 2-1) shows that the baseline air quality conditions in the vicinity of the Facility do not exceed the AQOs for NOx, NO_2, PM_{10} and $PM_{2.5}$ during 2021.

4.2 MSDC LOCAL AIR QUALITY MONITORING

MSDC monitors NO_2 using passive diffusion tubes (DT) at 33 monitoring locations. Most of the monitoring locations are over 5 km away from the Facility. Table 4-2 summarises the air quality data collected from the closest diffusion tube site to the Facility which is approximately 3 km south-west of the Facility.

Table 4-2: Nearest DT annual mean NO_2 concentrations (µg/m^3) (source: MSDC, 2021 ASR)

Site ID	Grid location (x, y)	Type	2016	2017	2018	2019	2020
MSAQ9 - Water Tower Colwood Lane Warninglid	525664, 125035	Rural	10	9	9	8.5	6.1

Comparing the background concentrations to the annual mean AQOs (as identified in Table 2-1) shows that the baseline air quality conditions in the vicinity of the Facility did not exceed the AQOs for NO_2 from 2016 to 2020.

4.3 SUSSEX AIR QUALITY NETWORK

MSDC is part of the Sussex Air Quality partnership who monitors air quality across Sussex using automatic real-time continuous monitors. Two of the automatic monitors are located in MSDC and they monitor NOx, NO_2 and/or PM_{10}. Table 4-3 summarises the recent air quality data collected from theses automatic monitors.

Table 4-3: Monitored annual mean NO_2 and PM_{10} concentrations (µg/m^3)

	Horsham - Cowfold	Horsham - Park Way
Grid location (x, y)	521500, 122497	517485, 130585
Type	Urban Traffic	Urban Traffic
Distance (km)	7.7	11.5
2021 Annual mean NO_2 concentrations (µg/m^3)	20.3	21.1
2021 Annual mean PM_{10} concentrations (µg/m^3)	NA	17.5

Comparing the background concentrations to the annual mean AQOs (as identified in Table 2-1) shows that the baseline air quality conditions at these Urban Traffic sites located 7.7 km and 11.5 km away from the Proposed Development did not exceed the AQOs for NO_2 from 2016 to 2020. Due to the location of these which are in close proximity to a road source, they are unlikely to be representative of air quality in the vicinity of the Facility which is in a rural location.

4.4 AUTOMATIC URBAN AND RURAL NETWORK

Hourly ozone and NO_2 for undertaking the chemistry reactions of nitrosamines and nitramines have been derived from the AURN sites at Lullington Heath. See more details in Appendix 1.

4.5 NON-AUTOMATIC HYDROCARBON NETWORK AND AUTOMATIC HYDROCARBON NETWORK

The non-automatic hydrocarbon network and automatic hydrocarbon network monitors several hydrocarbons using passive diffusion tubes and automatic monitors, respectively, across several locations in the UK. Annual mean benzene concentrations measured at the nearest sites to the Facility are provided in Table 4-4.

Table 4-4: Monitored annual mean benzene concentrations (µg/m^3)

	London Bloomsbury	Chilbolton Observatory	London Eltham	London Marylebone Road
Grid location (x, y)	530119, 182039	439390, 139078	543981, 174655	528126, 182015
Type	Urban Background	Rural Background	Suburban Background	Urban Traffic
Distance (km)	55	89	50	55
2017 concentrations (µg/m^3)	-	0.462 LDC	0.473	1.004
2018 concentrations (µg/m^3)	0.602	0.460	0.459	0.873
2019 concentrations (µg/m^3)	0.614	0.567 LDC	0.401	0.830 LDC
2020 concentrations (µg/m^3)	0.473	0.417 LDC	0.380	0.708
2021 concentrations (µg/m^3)	0.491	0.367 LDC	0.392	0.728

Note: LDC – low data capture of less than 75%

Comparing the background concentrations to the benzene annual mean AQO of 5 µg/m^3 (as identified in Table 2-1) shows that the baseline air quality conditions across several sites in the southeast of the UK, did not exceed the AQO for benzene from 2017 to 2021.

4.6 UKEAP: NATIONAL AMMONIA NETWORK

The UEKAP national ammonia network monitors ammonia using passive diffusion tubes, across several locations in the UK. Annual mean ammonia concentrations measured at the nearest sites to the Facility are provided in Table 4-5.

Table 4-5: Monitored annual mean ammonia concentrations (µg/m^3)

	Alice Holt 2	Thursley Common 2
Grid location (x, y)	480483, 142221	490698, 139919
Type	Rural Background	Rural Background
Distance (km)	50	40
2017 concentrations (µg/m^3)	0.721	0.675
2018 concentrations (µg/m^3)	0.871	1.134
2019 concentrations (µg/m^3)	0.625	0.885
2020 concentrations (µg/m^3)	0.605	0.890
2021 concentrations (µg/m^3)	0.641	0.771

Comparing the background concentrations to the ammonia annual mean EAL of 2,500 µg/m^3 (as identified in Table 2-2) shows that the baseline air quality conditions across the nearest sites, did not exceed the AQO for ammonia from 2017 to 2021.

4.7 OTHER LOCALLY MANAGED AUTOMATIC MONITORING

Several local authorities in the UK have established comprehensive automatic monitoring stations which monitor a suite of pollutants, including CO. The maximum daily 8-hour mean CO monitored concentrations at the closest sites to the Facility are provided in Table 4-6.

Table 4-6: Monitored maximum daily running carbon monoxide concentrations (mg/m^3)

	Birmingham Airport 2	Luton Airport FutureLuToN
Grid location (x, y)	417499, 284227	512578, 222204
Type	Suburban Industrial	Urban Industrial
Distance (km)	192	97
2017 concentrations (µg/m^3)	0.633	NA
2018 concentrations (µg/m^3)	0.957	NA
2019 concentrations (µg/m^3)	1.064	0.283
2020 concentrations (µg/m^3)	0.691	0.514
2021 concentrations (µg/m^3)	0.691	0.561

Comparing the maximum daily running carbon monoxide concentrations to the AQO of 10 mg/m^3 shows that the baseline air quality conditions across the nearest sites, do not exceed the AQO for CO from 2017 to 2021.

4.8 SUMMARY OF BASELINE USED IN ASSESSMENT

Air quality in the vicinity of the Facility complies with the relevant AQOs for human health. However, as a worst-case assessment, it has been assumed that the highest air quality concentrations associated with the current baseline are representative of the future baseline. Table 4-7 summarises the highest air quality concentrations for human receptors used to inform the impact assessment.

Table 4-7: Background concentrations used in the air quality assessment

Pollutant	Long term mean	Short term mean	Data Source
Nitrogen Dioxide (NO_2) (µg/m^3)	8.5	17	2019 data from nearest rural DT in MSDC (Table 4-2)
Particulates (PM_{10}) (µg/m^3)	13.47	13.47	Defra map (Table 4-1)
Fine Particulates ($PM_{2.5}$) (µg/m^3)	8.68	-	Defra map (Table 4-1)
Benzene (µg/m^3)	0.728	-	2021 highest data (Table 4-4)
Ammonia (µg/m^3)	0.771	-	2021 highest data (Table 4-5)
Carbon Monoxide (mg/m^3)		-	2021 highest data (Table 4-6)

Note:

(a) Based on LAQM.TG(22) Box 7.16 approach, where background short-term NO_2 is two times long term NO_2

(b) Based on LAQM.TG(22) Box 7.16 approach, where background short-term PM_{10} is equal to long term PM_{10}.

5. ASSESSMENT OF PREDICTED IMPACTS

5.1 MAXIMUM IMPACT ACROSS GRID

Modelling runs were carried out across a nested grid, comprising a coarse grid with 250 m receptor spacing to a 10 km radius around the Facility development, 50 m spacing within 2km of the Facility and a fine grid of 25 m spacing to a 500 m radius around the Facility.

Sensitivity analysis was carried out using five years of meteorological data from 2015 to 2019; these tests demonstrated that the worst-case meteorological year for this study is 2015. Table 5-1 presents the highest predicted PC to ground-level concentrations across the grid for all relevant pollutants in 2015.

Results are also presented for nitrosamines; details of the modelling methodology for nitrosamine formation are provided in Appendix A.

Table 5-1: Maximum Predicted Process Contributions (µg/m^3) Across Grid

Pollutant	Averaging Period	AQO or EAL	Max PC	Max PC as % of AQO/EAL
Benzene	Annual mean	5	1.31	**26%**
Carbon Monoxide	*Maximum daily running 8 hour mean*	*10*	*0.11*	*1%*
Nitrogen dioxide	Annual mean	40	27.44	**69%**
Nitrogen dioxide	*1-hour mean (99.79th percentile)*	*200*	*65.22*	***33%***
Particles	*24-hour mean (90.41st percentile)*	*50*	*6.92*	***14%***
Particles	Annual mean	40	4.07	**10%**
Hydrogen Cyanide	*1 hour mean (maximum)*	*220*	*2.83*	*1%*
Formaldehyde	*30-minute mean (maximum)*	*100*	*2.99*	*3%*
Formaldehyde	Annual mean	5	0.39	**8%**
Ammonia	Annual mean	2500	0.34	0.0%
Ammonia	*1 hour mean (maximum)*	*180*	*2.45*	*1.4%*
Acetaldehyde	Annual mean	370	0.62	0.2%
Acetaldehyde	*1 hour mean (maximum)*	*9200*	*4.43*	*0.05%*
MDEA	*1 hour mean*	*400*	***5.51***	***1.4%***
MDEA	*24 hour mean*	*100*	***2.17***	***2.2%***
Piperazine	*15-minute mean*	*30*	*1.52*	*5.1%*
Piperazine	*8-hour mean*	*1*	*0.96*	***96%***
Nitrosamine (as NDMA)	Annual mean	0.0002	0.000116	**54%**

Note:

Italics – Compared with 10% criteria for short term PC as % of standard

Non-italics - Compared with 1% criteria for long term PC as % of standard

Bold – exceeds 1% or 10%

Table 5-1 shows that the maximum long-term PC across the grid is above the 1% screening threshold of the long-term standards for benzene, NO_2, PM_{10}, formaldehyde, and nitrosamine, while the maximum short-term PC across the grid is above 10% of the short-term standards for NO_2 and PM_{10}, and 8-hour mean piperazine. All other pollutants are less than the 1% or 10% of the relevant short term and long-term standard and as such are screened out as insignificant and do not require further analysis.

Table 5-2 presents the resulting Predicted Environmental Concentrations (PEC) once the PC has been added to the background Ambient Concentration (AC) for the pollutants not yet screen out as insignificant. The PEC for each pollutant has then compared with the relevant AQO or EAL.

Table 5-2: Maximum Predicted Environmental Contributions (µg/m^3) Across Grid

Pollutant	Averaging Period	AQO or EAL	Background	Max PEC	Max PEC as % of AQO/EAL
Benzene	Annual mean	5	0.73	2.04	41%
Nitrogen dioxide	Annual mean	40	8.50	35.9	90%
Nitrogen dioxide	1-hour mean (99.79th percentile)	200	17.0	82.2	41%
Particles	24-hour mean (90.41st percentile)	50	13.47	20.4	41%
Particles	Annual mean	40	13.47	17.5	44%
Formaldehyde	Annual mean	5	0.00[(a)]	0.39	8%
Piperazine	8-hour mean	1	0.00[(a)]	0.96	96%
Nitrosamine (as NDMA)	Annual mean	0.0002	0.00[(a)]	0.108	54%

Note:

(a) Background levels are assumed to be zero as no existing industrial sources of formaldehyde, piperazine or nitrosamines have been identified in the study area.

Table 5-2 shows that all PECs for all pollutants are less than 100% of the relevant standard across the grid. Figure 5-1 and Figure 5-2 show contour maps of the annual mean process contributions for NO_2 and PM_{10}.

Figure 5-1: Contour map of modelled process contribution to annual mean NO_2 concentrations, 2015, (µg/m^3)

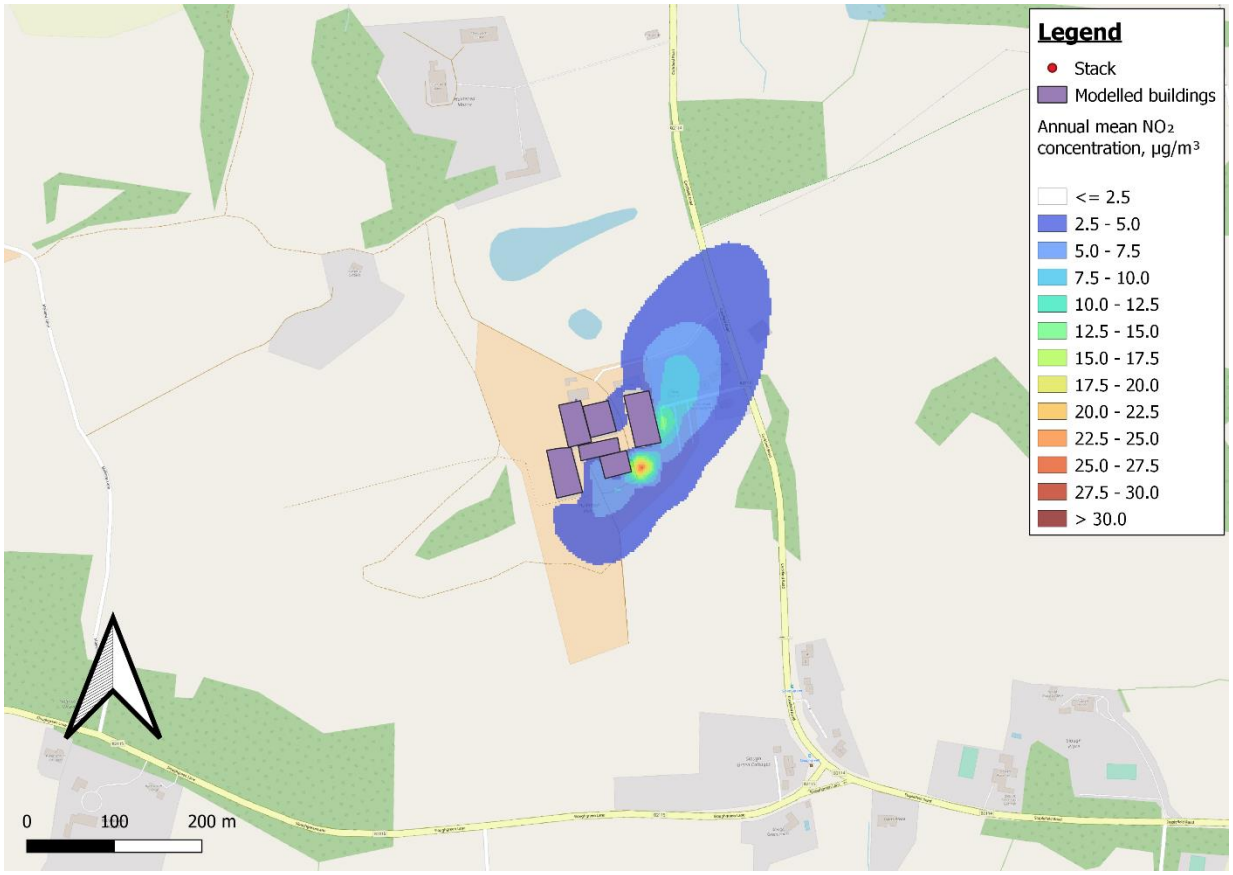
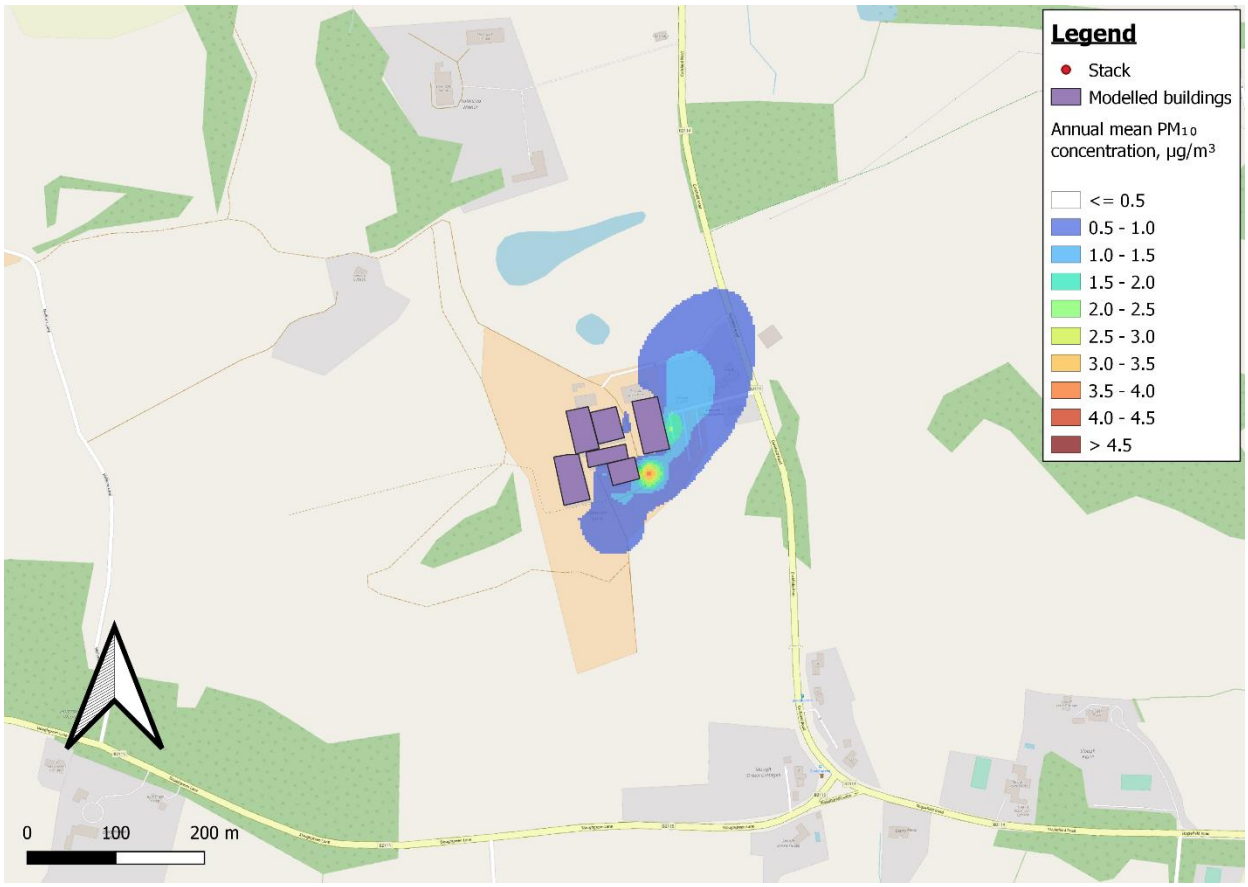


Figure 5-2: Contour map of modelled process contribution to annual mean PM_{10} concentrations, 2015, (µg/m^3)



From Figure 5-1 and Figure 5-2, it can be seen that the location of maximum impact in both cases does not occur at a relevant location for long-term human exposure. Instead, this maximum is predicted to occur immediately to the east of the stack. As such, the IAQM significance of impact criteria has not been applied to the maximum modelled PC and PEC as % of the AQO or EAL. The significance of the impact at relevant receptors is considered further in the following section 5.2.

5.2 MAXIMUM IMPACT AT HUMAN RECEPTORS

Table 5-3 presents the highest predicted PC to ground-level concentrations across the 41 selected sensitive receptors for all relevant pollutants.

Table 5-3: Maximum Predicted Process Contributions (µg/m^3) from the Facility at relevant receptors

Pollutant	Averaging Period	AQO or EAL	Max PC	Max PC as % of AQO/EAL
Benzene	Annual mean	5	0.44	**9%**
Carbon Monoxide	*Maximum daily running 8 hour mean*	*10*	*0.03*	*0%*
Nitrogen dioxide	Annual mean	40	9.14	**23%**
Nitrogen dioxide	*1-hour mean (99.79th percentile)*	*200*	*27.71*	***14%***
Particles	*24-hour mean (90.41 percentile)*	*50*	*3.21*	*6%*
Particles	Annual mean	40	1.36	**3%**
Hydrogen Cyanide	*1 hour mean (maximum)*	*220*	*1.05*	*0%*
Formaldehyde	*30-minute mean (maximum)*	*100*	*1.23*	*1%*
Formaldehyde	Annual mean	5	0.13	3%
Ammonia	Annual mean	2500	0.04	0%
Ammonia	*1 hour mean (maximum)*	*180*	*0.35*	*0%*
Acetaldehyde	Annual mean	370	0.09	0%
Acetaldehyde	*1 hour mean (maximum)*	*9200*	*0.70*	*0%*
MDEA	*1 hour mean*	*400*	2.15	0.5%
MDEA	*24 hour mean*	*100*	1.04	1.0%
Piperazine	*15-minute mean*	*30*	0.72	2.4%
Piperazine	*8-hour mean*	*1*	0.34	34.0%
Nitrosamine (as NDMA)	Annual mean	0.0002	0.00005	25.3%

Note:

Italics – Compared with 10% criteria for short term PC as % of standard

Non-italics - Compared with 1% criteria for long term PC as % of standard

Bold – exceeds 1% or 10%

Table 5-3 shows that the maximum long-term PC across the human receptors is above 1% of the long-term standards for benzene, NO_2, PM_{10}, formaldehyde, and nitrosamine, while the maximum short-term PC across the grid is above 10% of the short-term standards for NO_2 and piperazine.

All other pollutants are less than the 1% or 10% of the relevant short term and long-term standard and as such are screened out as insignificant and no longer considered for inclusion of background data.

Table 5-4 presents the resulting Predicted Environmental Concentrations (PEC) once the PC has been added to the background Ambient Concentration (AC) for the pollutants not yet screen out as insignificant. The PEC for each pollutant has then compared with the relevant AQO or EAL and the significance of impact described using the IAQM criteria.

Table 5-4: Maximum Predicted Environmental Contributions (µg/m^3) from the Facility at relevant receptors

Pollutant	Averaging Period	AQO or EAL	Background	Max PEC	Max PC as % of AQO/EAL	Impact descriptor
Benzene	Annual mean	5	0.73	1.17	23%	Minor
Nitrogen dioxide	Annual mean	40	8.50	17.6	44%	Moderate
Nitrogen dioxide	1-hour mean (99.79th percentile)	200	17.00	44.7	22%	Moderate
Particles	Annual mean	40	13.47	14.8	37%	Negligible
Formaldehyde	Annual mean	5	0.00 (a)	0.13	3%	Negligible
Piperazine	8-hour mean	1	0.00[(a)]	0.34	34%	Moderate
Nitrosamine (as NDMA)	Annual mean	0.0002	0.00[(a)]	0.00005	25.3%	Moderate

(a) Background levels are assumed to be zero as no existing industrial sources of formaldehyde, piperazine or nitrosamines have been identified in the study area.

The maximum PEC at nearby human receptors is described as minor to moderate impact for benzene and NO_2 at four receptors (R5 to R8). More details on the predicted concentrations of benzene and NO_2 at human receptors is provided in Appendix 1 and Appendix 3. For all the other receptors the significance of impact is negligible.

Despite the significance of impact being minor to moderate for a few pollutants at four receptors, Table 5-4 shows that the PEC is well below 70% of the AQO or EAL for all pollutants. The Facility is expected to operate at much lower emissions than the emissions limits as such, it is expected that the impact across all receptors will likely be of negligible significance in practice.

5.3 $PM_{2.5}$ MAXIMUM IMPACT AT RECEPTORS

Although $PM_{2.5}$ has not been explicitly modelled in this report, a conservative assessment can be carried out assuming that all PM_{10} is $PM_{2.5}$. With this worst-case assumption, the maximum predicted PC is 3.6% of the AQO, and the corresponding maximum PEC is 38% of the AQO. As such, applying the significance criteria described in Section 0, the significance of this impact can be described as negligible at sensitive receptors.

5.4 ASSESSMENT OF CUMULATIVE EFFECTS

Cumulative effects have been considered to the extent that the background concentrations used within the assessment take account of emissions of existing sources. Furthermore, there are no other industrial sources nearby. As such, cumulative effects are expected to be negligible.

5.5 MITIGATION MEASURES

No additional mitigation measures - save for those already incorporated into the design and operation of the Facility, are deemed to be required as the air quality impacts of the Facility are considered to be negligible.

The Facility will comply with the relevant Best Practice in order to ensure that air quality impacts are minimised.

6. CONCLUSION

A detailed modelling assessment has been carried out to assess the impact of the pilot BIOCCUS project on local air quality.

The assessment has used the dispersion model ADMS 5.2 to predict the increases in pollutant species released as a result of the emissions released during the operation of the Facility, using best practice approaches. The assessment has been undertaken based on several worse case assumptions including assuming that the facility would emit continuously at the emissions limits, however, emissions from the pilot study is expected to be much lower than the emissions limit.

The results of dispersion modelling indicate that Process Contributions and resultant Predicted Environmental Concentrations of all pollutants at human receptors are of negligible significance, except for benzene and NO_2 with a minor to moderate significance. However, this occurs at only four receptors out of the 41 receptors. Furthermore, the predicted environmental concentration at these receptors is well below the AQO and EAL (less than 70%).

Given that several worst-case assumptions have been adopted, it is expected that overall, the effects of the proposed Facility are likely to be of negligible significance.

APPENDICES

Appendix 1 - Amine Degradation

INTRODUCTION

This appendix presents the methodology used to assess the formation and dispersion of amine degradation products as a result of emissions from the Facility.

We have provided an indicative assessment to quantify potential impacts from the onsite process based on the best available data for ELVs, bearing in mind that there is significant uncertainty around potential emissions as this is a novel process. We have assumed that the amine system at the site will operate for 4000 hours per year for this assessment; in practice, the operating hours for the carbon capture process are unlikely to exceed 2000 hours per year. For assessment against short-term EALs, the site has been assumed to operate continuously in order to ensure that worst-case meteorological conditions are accounted for.

Should we request that the scope of the site be expanded to include longer-term commercial use in future, we will provide a detailed assessment using updated emissions from onsite monitoring and assess against the EALs for piperazine to be published in 2024.

The Facility will use an amine capture process to remove carbon dioxide (CO_2) through reaction with amine-based solvents. Amines are organic derivatives of ammonia (NH_3) with one or more hydrogen atoms replaced by an organic group (R), and can be characterised as primary, secondary or tertiary depending on how many hydrogen atoms (H-atoms) are replaced by organic groups:

- Primary amines (R-NH2) where 1 H-atom is replaced;
- Secondary amines (R2-NH) where 2 H-atoms are replaced;
- Tertiary amines (R3-N) where 3 H-atoms are replaced.

Amines degrade in the atmosphere to form other species, including:

- Nitrosamines, hydrocarbons with the generic chemical formula of (R1R2)-N-N=O, where R1 and R2 are alky groups. Nitrosamines are formed through reaction with nitrogen monoxide. Secondary and tertiary amines can degrade to form stable nitrosamines, while primary amines do not.
- Nitramines, hydrocarbons with the generic chemical formula (R1R2)-N-NO2, where R1 and R2 are alky groups. Nitramines are formed through reaction with nitrogen dioxide.

These are collectively referred to as “N-amines” Some of these degradation products are potentially carcinogenic.

The reactions involved in this process are complex, and the rate of formation of N-amines depends on a range of factors. As a result, the modelling process for these emissions is more complex than that for other pollutants, so additional model inputs and sensitivity testing are required in order to assess the significance of impacts from the onsite processes.

The solvent to be used in the amine capture process in the Proposed Development is Methyl Diethanolamine (MDEA), a tertiary amine, with a smaller amount of Piperazine (PZ) also in the same solvent mixture. This assessment includes both direct N-amine emissions from the process stack, and secondary formation of N-amines from amine emissions.

This amine degradation study was carried out following the guidance note “AQMAU recommendations for the regulation of impacts to air quality from amine-based post-combustion carbon capture plant”, published by the Environment Agency in 2020.

ENVIRONMENTAL ASSESSMENT LEVELS

In September 2021, the Environment Agency published Environmental Assessment Levels (EALs) for mono-ethanolamine (MEA) and N-nitroso-dimethylamine (NDMA). These EALs are detailed in Table A1-1.

NDMA is the main nitrosamine produced through the degradation of DMA. NDMA is highly hepatoxic and is a known carcinogen in laboratory animals, and as a result is one of the most closely studied nitrosamines. The EAL for NDMA has been applied to all N-amines in this study order to ensure that the assessment is as conservative as possible.

Table A1.1: Environmental Assessment Levels (EALs)

Pollutant	Measured As	Objective
Mono-ethanolamine (MEA) [(a)]	1 hour mean	400 µg/m^3
	24 hour mean	100 µg/m^3
N-nitrosodimethylamine (NDMA) [(a)]	Annual mean	0.0002 µg/m^3

Note: (a) Assumed to be representative of amines, nitrosamines and nitramines

The specific solvents to be used in this study are MDEA and piperazine, in a 4:1 ratio.

For MDEA, the ECHA report a NOAEC of 19.9 mg/m^3 and a DNEL of 0.4 mg.m^{-3} for the general population for hazards via the inhalation route. Using the NOAEC as the POD (which is 1.98 x the POD used in the derivation of the EALs for MEA) and applying an Uncertainty Factor of 25 for the short-term EAL and 100 for the long-term EAL, in line with the approach taken for MEA, gives the following EALs:

Table A1.2: Derived EALs for MDEA

Averaging period	NOAEC (mg.m^{-3})	UF	Derived EAL	MEA EAL (for comparison)
1 hour	19.9	25	0.796 mg/m^3	0.4 mg/m^3
24 hour		100	0.199 mg/m^3	0.1 mg/m^3

The MEA EAL is lower than the corresponding derived EALs for MDEA. As a result, we have assessed MDEA concentrations against the MEA EAL to ensure a conservative assessment.

For piperazine, the EU RAR (2005) indicates that there is 'no adequate data' for inhalation toxicity, and to our knowledge no NOAEC/LOAEC is available from standard sources.

We understand that the Environment Agency is currently developing EALs for piperazine which will not be published within the timescales of this initial study. However, Occupational Exposure Limits are available (Commission Directive 2000/39/EC of 8 June 2000). As such, for this initial assessment indicative EALs for piperazine have been derived using the older Environment Agency approach, whereby the STEL is divided by 10, and the LTEL is divided by 100, giving the following indicative EALs outlined in Table A-2. Should the scope of the activities on site be expanded in future a separate application will be submitted using the Environment Agency EALs and updated emissions rates from onsite monitoring.

Table A1-3: OELs and derived indicative EALs for piperazine

Type	Averaging period	OEL (mg.m^{-3})	Indicative derived EAL (mg.m^{-3})
LTEL (mg/m^3)	8 hours	0.1	0.001
STEL (mg/m^3)	15 minutes	0.3	0.03

DISPERSION MODELLING METHODOLOGY

Scope of the assessment

This section describes the additional inputs and choice of data used in the amine chemistry modelling. All other inputs were kept as described in the main report. The approach to the assessment of emissions from the proposed Facility comprises the following key elements:

- Assessment of Process Contributions (PC) from the Facility in isolation, and assessment of resultant Predicted Environmental Concentrations (PEC); and
- Determining the significance of the impact on human receptors using the EA and IAQMA/EPUK significance criteria.

Dispersion model

The amine chemistry module in ADMS 5 was used for the assessment. This is an extension to the NOx chemistry scheme available in the model, and is currently the sole commercially available modelling software for evaluation of the potential impacts from amines and amine degradation products. The amine chemistry module is based on established science, considering published research on mechanisms of formation of toxic compounds. The core ADMS 5 dispersion model is described in the main report.

The primary method for formation of N-amines in the atmosphere is a two-step process:

1. Oxidation of the amine by the OH (fast) or NO_3 (slow) radical to for an unstable amino radical. The OH radical is generated during the day by photolysis of H_2O.
2. Reaction of the amino radical with an NO group to form a nitrosamine, or an NO_2 group to form a nitramine.

Competing reactions also take place, preventing the formation of N-amines.

- The amine can degrade to other radical species. The potential for formation of other radical species is referred to as the “branching ratio”.
- The amine radical can react to form a stable imine.
- The N-amine can undergo additional reactions or reverse react back to the radical.

Atmospheric N-nitrosamine concentrations are a steady-state balance of the rate of formation from ongoing emissions of amines and the rapid rate of removal through further reaction and wash out. The amine chemistry scheme in ADMS 5 calculates steady state concentrations based on derived reaction rates for each of these reactions, as illustrated in Figure A1.1. The module is designed so that it can be applied to a variety of amines, including both primary amines (which do not form stable nitrosamines) and secondary or tertiary amines (which can form stable nitrosamines) provided the amine-specific information on atmospheric reactions is available.

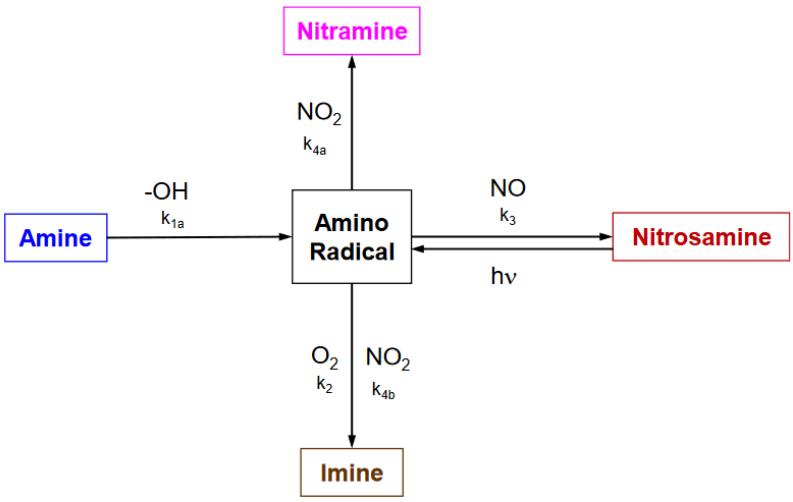


Figure A1.1: Schematic diagram showing the amine chemistry module in ADMS 5 (adapted from ADMS 5 amine module user guide)

Chemistry model parameters

A literature review was carried out to identify parameters for use in the amine chemistry module. Limited information is available in the literature for reaction rate constants for amine degradation; the majority of published research focuses on the degradation of a limited number of primary and secondary amines:

monoethanolamine (MEA), monomethyl amine (MMA) and dimethyll amine (DMA). There is limited information available for tertiary amines such as MDEA.

As the available reaction kinetic information is limited, in this assessment the solvent used has been modelled as both MEA and DMA. The worst-case concentrations between these two species have then been used as the basis for the assessment.

Unlike primary amines, tertiary amines are able to degrade to form stable nitrosamines. However, tertiary amines do not feature a labile -H group, and as a result their propensity to form nitrosamines is limited compared to secondary amines such as DMA. As the primary and secondary amines modelled represent extreme cases compared to MDEA, this approach should provide allow a robust assessment of the range of impacts potentially possible from use of MDEA as a solvent; in particular, it is expected that modelling the release as DMA will provide a strongly worst-case assessment of potential impacts.

Table A1.4 presents the reaction constants used for the MEA and DMA models. Where multiple values are available in the literature, the average value for each parameter has been used. Sensitivity testing was carried out into the range of potential chemistry model parameters; this sensitivity testing is described below.

Table A1.4: Reaction rate constants and other parameters used in the ADMS amine chemistry module

Parameter	MEA	DMA	Source(s)
k1: Amine/OH radical reaction rate constant, $ppb^{-1}.s^{-1}$	2.1	1.6	CERC (2012) [3] Lee & Wexler (2013)[4]
k2: Rate constant for formation of nitrosamine, $ppb^{-1}.s^{-1}$	$4.91x10^{-8}$	$4.61 x10^{-8}$	CERC (2012) Manzoor (2014)[5]
k3: Rate constant for formation of nitrosamine, $ppb^{-1}.s^{-1}$	0.0037	0.0021	CERC (2012) Manzoor (2014)
k4a: Rate constant for formation of nitramine, $ppb^{-1}.s^{-1}$	0.0040	0.0078	CERC (2012) Manzoor (2014)
k4: Amino radical/NO_2 reaction rate constant, $ppb^{-1}.s^{-1}$	0.0045	0.0089	CERC (2012) Manzoor (2014)
Branching ratio	0.10	0.40	CERC (2012) Manzoor (2014) Lee & Wexler (2013)
Ratio of J (nitrosamine) to NO_2	0	0.39	Nielson (2010)
OH concentration constant c, s	0.0023	0.0023	CERC (2012) Jackson et al. (2009)

In order to provide a worst-case assessment of amine concentrations, amine dispersion was modelled without the amine chemistry module activated to prevent removal of amines by chemical processes.

[3] Cambridge Environmental Research Consultants (2012). Contract number 257430174: Atmospheric Chemistry Modelling. Prepared for CO2 Capture Mongstad Project Gassnova SF.

[4] Lee, DongYoub & Wexler, Anthony. (2013). Atmospheric amines – Part III: Photochemistry and toxicity. Atmospheric Environment. 71. 95–103. 10.1016/j.atmosenv.2013.01.058.

[5] Manzoor et al., 2014. Atmospheric chemistry modelling of amine emissions from post combustion CO_2 capture technology. Energy Procedia, 63, 822-829. 2014.

Emissions to air

Table A1.5 presents the modelled emissions to air of the amine solvent (MDEA), and direct nitrosamine emissions.

Amine emissions have been modelled at a limit concentration of 20 mg/Nm^3, using the Emission limit value from TA-LUFT Annex 4 Class I pursuant to Section 5.2.5. Although MDEA is not itself specified within Annex 4 of T-LUFT, other amines (including MEA) are classed as "organic substances of Class I pursuant to [Section] 5.2.5". The maximum combined emissions for all Class I substances is used in the assessment, assuming all emissions are MDEA. A reference %O_2 of 5% has been assumed for the purposes of the emissions calculations.

Direct N-amine emissions have been considered at an emission limit of 0.002 mg/Nm^3 for NDMA based on the worst-case assessment carried out for the Net Zero Teesside site. These levels were based on maximum potential concentrations provided for licensors for that project, and are considered to be representative of potential worst-case direct emissions of NDMA from the Facility. A reference %O_2 of 15% has been assumed for the purposes of the emissions calculations.

The use of these emission limits is considered to represent a worst-case scenario, as in practice the Facility is not likely to give rise to emissions at these levels. Furthermore, assessing all emissions against the worst-case EAL for NDMA concentrations is considered to ensure that the assessment is as conservative as possible.

Table A1.5: Mass Emissions of Released Pollutants

Pollutants	Emission limit (mg/Nm^3) @ (O^0C, dry)	Refence %O_2	Mass Emission (g/s), FGR	Mass Emission (g/s) no FGR
NDMA (primary emissions)	0.002[(a)]	15	1.760 x10^{-6}	1.792 x10^{-6}
MDEA and piperazine	20[(a)]	5	0.006533	0.006650
MDEA	-	5	0.005226	0.00532
Piperazine	-	5	0.001307	0.00133

a) Process-specific concentrations are not available at this stage, so we have used the maximum emissions concentration provided by licensors at other similar sites, including the Net Zero Teesside site:
Net Zero Teesside – Environmental Statement Appendix 8C: Air Quality Assessment of Amine Degradation Products
and
Keadby 3 Low Carbon Gas Power Station Project: Environmental Statement Volume II - Appendix 8C: Air Quality Assessment of Amine Degradation Products
The amine solvent to be used is 80% MDEA and 20% piperazine; total amine emissions have been apportioned on this basis.

A literature review carried out for this study indicated that there is limited kinetic information is available for the degradation of MDEA to N-amines. As such, model runs have been carried out following two sets of assumptions:

1. assuming that this release is MEA (a primary amine solvent); and
2. assuming that this release is DMA (a secondary amine solvent).

The worst case of these two assumptions has been used as the basis for the assessment.

Background Concentrations

Model guidance states that use of hourly background measurements is highly recommended when using the amine chemistry module in ADMS 5. As such, this approach has been used for the assessment, in contrast with the assessment of other pollutant concentrations.

Hourly NO_2, NOx and O_3 measurements were obtained from Defra's Automatic Urban and Rural Network (AURN). Data was taken from the Lullington Heath monitoring site, located 32km to the southeast of the Proposed Development, as this is the closest background site for which all three pollutants are available with sufficient data capture to be used in the study.

Gaps in the measurements were filled through the following stages:

1. Gaps up to 3 hours were filled through linear interpolation between the nearest recorded values;
2. Larger gaps were filled using an averaged diurnal profile of concentrations for each year at the site.

Table A1.6 presents summary statistics for the background data used in the amine degradation assessment.

Table A1.6: Annual average concentrations at the Lullington Heath AURN site

Parameter	2015	2016	2017	2018	2019
NOx	8.1	9.1	8.9	8.6	8.2
NO_2	7.0	7.8	7.7	7.6	7.2
O_3	56.6	55.0	55.4	61.1	61.3

Sensitivity testing was carried out into the use of background concentrations from nearby roadside sites; this testing indicated that use of data from the Lullington Heath station provides a worst-case assessment of impacts from the Facility.

UNCERTAINTY ANALYSIS

There are a number of additional uncertainties to those described in Section 3.5 associated specifically with the amine degradation modelling. These arise from the limitations and uncertainties in the model methodology, and in the input parameters used in the model. These limitations, together with an assessment of their likely impacts, are described below.

Uncertainty in chemistry parameters

There is limited published data available for the reaction rate constants and other parameters for amine degradation in general. The literature analysis carried out in support of this study indicated complete sets of reaction rates are only available for a small number of amine species, including MEA, DMA, and MMA, but not NMEA, the solvent to be used at the Proposed Development.

As a result, sensitivity testing around the parameters used in the assessment was required to provide a sense of the model uncertainty around reaction kinetics for MDEA; to address this uncertainty, the release was modelled as both MEA and DMA (both of which are degradation products of NMEA). In this study, the results for the worse of the two cases have been presented and assessed in order to ensure that the assessment of potential impacts is worst-case. Sensitivity testing showed that reaction kinetics for DMA provide a worst-case assessment of potential amine degradation impacts.

Limitations in the ADMS amine module

The amines module itself has not been validated, and the limitations of the model are described below. Despite these limitations, it is considered that the ADMS amine module is a suitable tool for use in this assessment given the many worst-case assumptions that have been made as part of the assessment methodology. The module is based on first principles and established science, and has been used in similar studies for this purpose.

1. **No time-delay in N-amine formation**

   The amine chemistry does not account for the time delay in the initiation of the amine degradation, which indicates only around 15% reaction completion within 1 hour.

2. **N-amine degradation processes not accounted for**

   No destruction of N-amines by photolysis is included in the model. Also no photolysis of direct N-amine emissions.

3. **Only day-time reactions considered**

   The ADMS amine module only considers reactions with OH, and does not include night time reaction with the NO_3 radical; these night time reactions are expected to be a secondary source of N-amine concentrations.

   Modelling undertaken by CERC indicates that reactions with OH radicals (i.e. daytime reactions) are dominant, supporting the approach taken by the ADMS amine module.[6]

4. **No consideration of phase partitioning**

   Amines and N-amines undergo transformation through complex chemical reactions and deposition (AQMAU). These processes involve multiphase chemistry. As a result, the mass of starting amine and products may be partitioned into the aqueous phase, reducing pollutant concentrations in air. As per AQMAU, publications associated with the Mongstad pilot plant (e.g. Gjernes 2013)[7] indicate that the formation of toxic products in ambient air was dominated by gas phase reactions, supporting the current version of the ADMS amines module.

5. **Background values**

   The model is sensitive to the hourly background data used in the assessment. However, there are no nearby sites for which hourly NOx, NO_2 and O_3 data are available, so the rural background Lullington Heath site was used in the assessment.

   To ensure that this approach provides a conservative estimate of admien degradation product impacts, a sensitivity test was carried out using NOx and NO2 concentrations from the Storrington AURN site.

[6] https://ukccsrc.ac.uk/wp-content/uploads/2021/11/AQMAU-C2025-RP01.pdf

[7] Gjernes et al., 2013: Health and environmental impact of amine based post combustion CO_2 capture. 2013.

This is a roadside site, and as a result reports substantially higher concentrations of NOx and NO_2 which will be overpredictions relative to the concentrations expected at the Proposed Development.

Worst-case assumptions:

In order to minimise the likelihood of under-estimating the N-amine PC to ground level concentrations from the main stack as a result of the limitations and uncertainties described above, the following conservative assumptions have been made as part of this assessment:

- The operational Proposed Development has been assumed to operate for 4000 hours per year, although in practice the plant is unlikely to operate for more than 2000 hours per year;
- To account for variability in meteorological conditions, concentrations have been predicted using five full years of meteorological data. The assessment of the significance of impacts from the Proposed Development has been carried out on the basis of the worst-case year.
- Modelling has been run for two operational scenarios: a 35% FGR scenario, expected to represent the likely operating conditions, and a worst-case scenario with no FGR (and hence higher pollutant emissions).
- Emission concentrations of amines have been based on the maximum permitted levels at other sites, rather than based on the expected emissions from the technology in question;
- All N-amines have been assessed against the AQAL for NDMA, when it is likely that there will be different N-amine species present in the PC, the majority of which will be less toxic than NDMA.

DISPERSION MODELLING RESULTS

Amine concentrations

Table A1.7 and Table A1.8 present the maximum predicted PCs for 1-hour mean and 24-hour mean MDEA concentrations at nearby residential receptors, for comparison with the relevant EALs for MEA. The maximum predicted PCs to amine concentrations across the entire modelled receptor grid are also presented. For each receptor, results for the worst-case meteorological year are presented. Results are presented for both the expected 35% FGR scenario, and the worst-case scenario with no FGR.

As the maximum PC to 1-hour mean MDEA concentrations is less than 10% of the EAL at all modelled locations for both modelled scenarios, the impact from the Facility on 1-hour mean MEA concentrations can be screened out as insignificant.

Similarly, the maximum PC to maximum 24-hour mean MDEA concentrations is less than 10% of the EAL at all modelled receptors for both modelled scenarios. As a result, the impact from the Facility on 24-hour mean MEA concentrations can be screened out as insignificant.

Tables A1.9 and A1.10 present the maximum predicted PCs for 15-minute mean and 8-hour mean piperazine concentrations at nearby receptors, for comparison with the indicative derived EALs for piperazine.

As the maximum PC to 15-minute mean piperazine concentrations is less than 10% of the indicative EAL at all modelled locations for both modelled scenarios, the impact from the Facility can be screened out as insignificant. The maximum PC to 8-hour mean piperazine concentrations across the modelled grid is classified as “substantial”, while a “moderate” impact is predicted at 4 sensitive receptors. However, these predictions assume that the carbon capture process runs continuously; in practice, the process will not run for more than 4000 hours per year, and no exceedances of the indicative EAL are predicted to occur at any modelled locations in the worst-case meteorological year when assuming that the carbon capture process operates continuously.

Figure A1-2 presents the maximum modelled PC to 8-hour mean piperazine concentrations across all modelled years and scenarios.

Table A1.7: Maximum predicted PCs to 1-hour mean MDEA concentrations between 2015 and 2019, and comparison against the EAL for MEA

ID	Receptor Location	No FGR		35% FGR		Impact descriptor
		PC & PEC (µg/m^3)	PC & PEC as % of EAL	PC & PEC (µg/m^3)	PC & PEC as % of EAL	
-	Maximum across grid	4.62	1.16%	5.51	1.38%	Screened out
R1	Cuckfield Road 4	1.05	0.26%	1.16	0.29%	Screened out
R2	Cuckfield Road 2	0.77	0.19%	0.87	0.22%	Screened out
R3	Cuckfield Road 22	0.69	0.17%	0.72	0.18%	Screened out
R4	Slough Place Farm	1.31	0.33%	1.54	0.38%	Screened out
R5	Holmstead Farm	1.16	0.29%	1.34	0.34%	Screened out
R6	Holmstead Farm	1.77	0.44%	2.15	0.54%	Screened out
R7	Holmstead Farm	1.05	0.26%	1.21	0.30%	Screened out
R8	Hollyhus	0.40	0.10%	0.46	0.12%	Screened out
R9	Holmsted Manor	0.41	0.10%	0.48	0.12%	Screened out
R10	Holmsted Manor 2	0.29	0.07%	0.30	0.08%	Screened out
R11	The Coach House	0.44	0.11%	0.49	0.12%	Screened out
R12	Mallion's Farm	0.58	0.15%	0.69	0.17%	Screened out
R13	Slough Green Cottage	0.69	0.17%	0.76	0.19%	Screened out
R14	Slough Place Cottage	0.40	0.10%	0.43	0.11%	Screened out
R15	Cleavers Barn	0.42	0.10%	0.45	0.11%	Screened out

ID	Receptor Location	No FGR		35% FGR		Impact descriptor
		PC & PEC (µg/m^3)	PC & PEC as % of EAL	PC & PEC (µg/m^3)	PC & PEC as % of EAL	
R16	Cleavers Cottage	0.38	0.09%	0.42	0.10%	Screened out
R17	Mizbrooks House	0.15	0.04%	0.18	0.05%	Screened out
R18	Winscot	0.12	0.03%	0.14	0.04%	Screened out
R19	Oakfield House	0.45	0.11%	0.49	0.12%	Screened out
R20	Moorfields Farm Cott	0.44	0.11%	0.48	0.12%	Screened out
R21	Moorfields Farmhouse	0.43	0.11%	0.45	0.11%	Screened out
R22	Moorfields	0.39	0.10%	0.43	0.11%	Screened out
R23	Fowlers	0.24	0.06%	0.26	0.06%	Screened out
R24	Spencer Barn	0.24	0.06%	0.26	0.07%	Screened out
R25	Barsnape Farm	0.19	0.05%	0.21	0.05%	Screened out
R26	Broxmead Farm	0.19	0.05%	0.22	0.06%	Screened out
R27	Oak Wood House	0.24	0.06%	0.26	0.07%	Screened out
R28	Great Thorndean Farm	0.23	0.06%	0.25	0.06%	Screened out
R29	Little Domick	0.16	0.04%	0.19	0.05%	Screened out
R30	Wych Cottage	0.25	0.06%	0.28	0.07%	Screened out
R31	Bigges Farm 1	0.17	0.04%	0.20	0.05%	Screened out
R32	The Forge	0.19	0.05%	0.23	0.06%	Screened out
R33	Red House	0.21	0.05%	0.22	0.06%	Screened out
R34	Amberstone	0.38	0.10%	0.50	0.12%	Screened out
R35	Slough Green House	0.65	0.16%	0.71	0.18%	Screened out
R36	Deaks Mead	0.26	0.07%	0.29	0.07%	Screened out
R37	Hazelbrook Farm	0.29	0.07%	0.33	0.08%	Screened out
R38	Barsnape Lodge	0.29	0.07%	0.34	0.08%	Screened out
R39	Barnsnape Lodge	0.46	0.12%	0.53	0.13%	Screened out
R40	Paternosters Cottage	0.45	0.11%	0.48	0.12%	Screened out
R41	Deaks	0.01	0.00%	0.02	0.00%	Screened out

Table A1.8: Maximum predicted PCs to 24-hour mean MDEA concentrations between 2015 and 2019, and comparison against the EAL for MEA

ID	Receptor Location	No FGR		35% FGR		Impact descriptor
		PC & PEC (µg/m^3)	PC & PEC as % of EAL	PC & PEC (µg/m^3)	PC & PEC as % of EAL	
-	Maximum across grid	1.64	1.64%	2.17	2.17%	Screened out
R1	Cuckfield Road 4	0.26	0.26%	0.30	0.30%	Screened out
R2	Cuckfield Road 2	0.16	0.16%	0.17	0.17%	Screened out
R3	Cuckfield Road 22	0.22	0.22%	0.28	0.28%	Screened out
R4	Slough Place Farm	0.90	0.90%	1.04	1.04%	Screened out
R5	Holmstead Farm	0.73	0.73%	0.79	0.79%	Screened out
R6	Holmstead Farm	0.65	0.65%	0.70	0.70%	Screened out
R7	Holmstead Farm	0.60	0.60%	0.65	0.65%	Screened out

ID	Receptor Location	No FGR		35% FGR		Impact descriptor
		PC & PEC (µg/m^3)	PC & PEC as % of EAL	PC & PEC (µg/m^3)	PC & PEC as % of EAL	
R8	Hollyhus	0.10	0.10%	0.10	0.10%	Screened out
R9	Holmsted Manor	0.08	0.08%	0.08	0.08%	Screened out
R10	Holmsted Manor 2	0.06	0.06%	0.06	0.06%	Screened out
R11	The Coach House	0.04	0.04%	0.05	0.05%	Screened out
R12	Mallion's Farm	0.16	0.16%	0.18	0.18%	Screened out
R13	Slough Green Cottage	0.21	0.21%	0.28	0.28%	Screened out
R14	Slough Place Cottage	0.13	0.13%	0.17	0.17%	Screened out
R15	Cleavers Barn	0.09	0.09%	0.12	0.12%	Screened out
R16	Cleavers Cottage	0.10	0.10%	0.13	0.13%	Screened out
R17	Mizbrooks House	0.03	0.03%	0.04	0.04%	Screened out
R18	Winscot	0.03	0.03%	0.04	0.04%	Screened out
R19	Oakfield House	0.13	0.13%	0.15	0.15%	Screened out
R20	Moorfields Farm Cott	0.14	0.14%	0.16	0.16%	Screened out
R21	Moorfields Farmhouse	0.14	0.14%	0.16	0.16%	Screened out
R22	Moorfields	0.12	0.12%	0.14	0.14%	Screened out
R23	Fowlers	0.07	0.07%	0.09	0.09%	Screened out
R24	Spencer Barn	0.07	0.07%	0.09	0.09%	Screened out
R25	Barsnape Farm	0.07	0.07%	0.08	0.08%	Screened out
R26	Broxmead Farm	0.03	0.03%	0.03	0.03%	Screened out
R27	Oak Wood House	0.03	0.03%	0.04	0.04%	Screened out
R28	Great Thorndean Farm	0.04	0.04%	0.05	0.05%	Screened out
R29	Little Domick	0.02	0.02%	0.03	0.03%	Screened out
R30	Wych Cottage	0.07	0.07%	0.09	0.09%	Screened out
R31	Bigges Farm 1	0.02	0.02%	0.03	0.03%	Screened out
R32	The Forge	0.03	0.03%	0.04	0.04%	Screened out
R33	Red House	0.04	0.04%	0.05	0.05%	Screened out
R34	Amberstone	0.12	0.12%	0.13	0.13%	Screened out
R35	Slough Green House	0.12	0.12%	0.15	0.15%	Screened out
R36	Deaks Mead	0.08	0.08%	0.10	0.10%	Screened out
R37	Hazelbrook Farm	0.05	0.05%	0.06	0.06%	Screened out
R38	Barsnape Lodge	0.06	0.06%	0.07	0.07%	Screened out
R39	Barnsnape Lodge	0.06	0.06%	0.06	0.06%	Screened out
R40	Paternosters Cottage	0.15	0.15%	0.19	0.19%	Screened out
R41	Deaks	0.00	0.00%	0.00	0.00%	Screened out

Table A1.9: Maximum predicted PCs to 15-minute mean piperazine concentrations between 2015 and 2019, and comparison against the indicative EAL for piperazine

ID	Receptor Location	No FGR		35% FGR		Impact descriptor
		PC & PEC ($\mu g/m^3$)	PC & PEC as % of EAL	PC & PEC ($\mu g/m^3$)	PC & PEC as % of EAL	
-	Maximum across grid	1.17	3.89%	1.52	5.07%	Screened out
R1	Cuckfield Road 4	0.37	1.24%	0.42	1.40%	Screened out
R2	Cuckfield Road 2	0.29	0.95%	0.32	1.08%	Screened out
R3	Cuckfield Road 22	0.29	0.96%	0.31	1.04%	Screened out
R4	Slough Place Farm	0.36	1.19%	0.42	1.39%	Screened out
R5	Holmstead Farm	0.37	1.23%	0.43	1.45%	Screened out
R6	Holmstead Farm	0.60	1.98%	0.72	2.41%	Screened out
R7	Holmstead Farm	0.34	1.13%	0.39	1.30%	Screened out
R8	Hollyhus	0.15	0.49%	0.17	0.56%	Screened out
R9	Holmsted Manor	0.15	0.50%	0.17	0.58%	Screened out
R10	Holmsted Manor 2	0.11	0.37%	0.12	0.40%	Screened out
R11	The Coach House	0.19	0.64%	0.21	0.71%	Screened out
R12	Mallion's Farm	0.20	0.66%	0.24	0.79%	Screened out
R13	Slough Green Cottage	0.29	0.95%	0.33	1.10%	Screened out
R14	Slough Place Cottage	0.18	0.60%	0.20	0.65%	Screened out
R15	Cleavers Barn	0.19	0.63%	0.20	0.67%	Screened out
R16	Cleavers Cottage	0.16	0.53%	0.18	0.60%	Screened out
R17	Mizbrooks House	0.05	0.17%	0.06	0.20%	Screened out
R18	Winscot	0.05	0.17%	0.06	0.20%	Screened out
R19	Oakfield House	0.20	0.67%	0.22	0.74%	Screened out
R20	Moorfields Farm Cott	0.19	0.65%	0.22	0.73%	Screened out
R21	Moorfields Farmhouse	0.19	0.65%	0.21	0.71%	Screened out
R22	Moorfields	0.18	0.60%	0.20	0.67%	Screened out
R23	Fowlers	0.11	0.37%	0.12	0.41%	Screened out
R24	Spencer Barn	0.11	0.37%	0.13	0.42%	Screened out
R25	Barsnape Farm	0.09	0.30%	0.10	0.34%	Screened out
R26	Broxmead Farm	0.08	0.27%	0.09	0.31%	Screened out
R27	Oak Wood House	0.09	0.30%	0.11	0.35%	Screened out
R28	Great Thorndean Farm	0.11	0.35%	0.12	0.38%	Screened out
R29	Little Domick	0.07	0.22%	0.07	0.24%	Screened out
R30	Wych Cottage	0.11	0.37%	0.12	0.41%	Screened out
R31	Bigges Farm 1	0.05	0.16%	0.06	0.18%	Screened out
R32	The Forge	0.05	0.16%	0.06	0.19%	Screened out
R33	Red House	0.10	0.32%	0.10	0.34%	Screened out
R34	Amberstone	0.15	0.49%	0.17	0.57%	Screened out
R35	Slough Green House	0.25	0.83%	0.28	0.93%	Screened out
R36	Deaks Mead	0.12	0.41%	0.14	0.47%	Screened out
R37	Hazelbrook Farm	0.11	0.38%	0.14	0.46%	Screened out
R38	Barsnape Lodge	0.11	0.38%	0.14	0.48%	Screened out

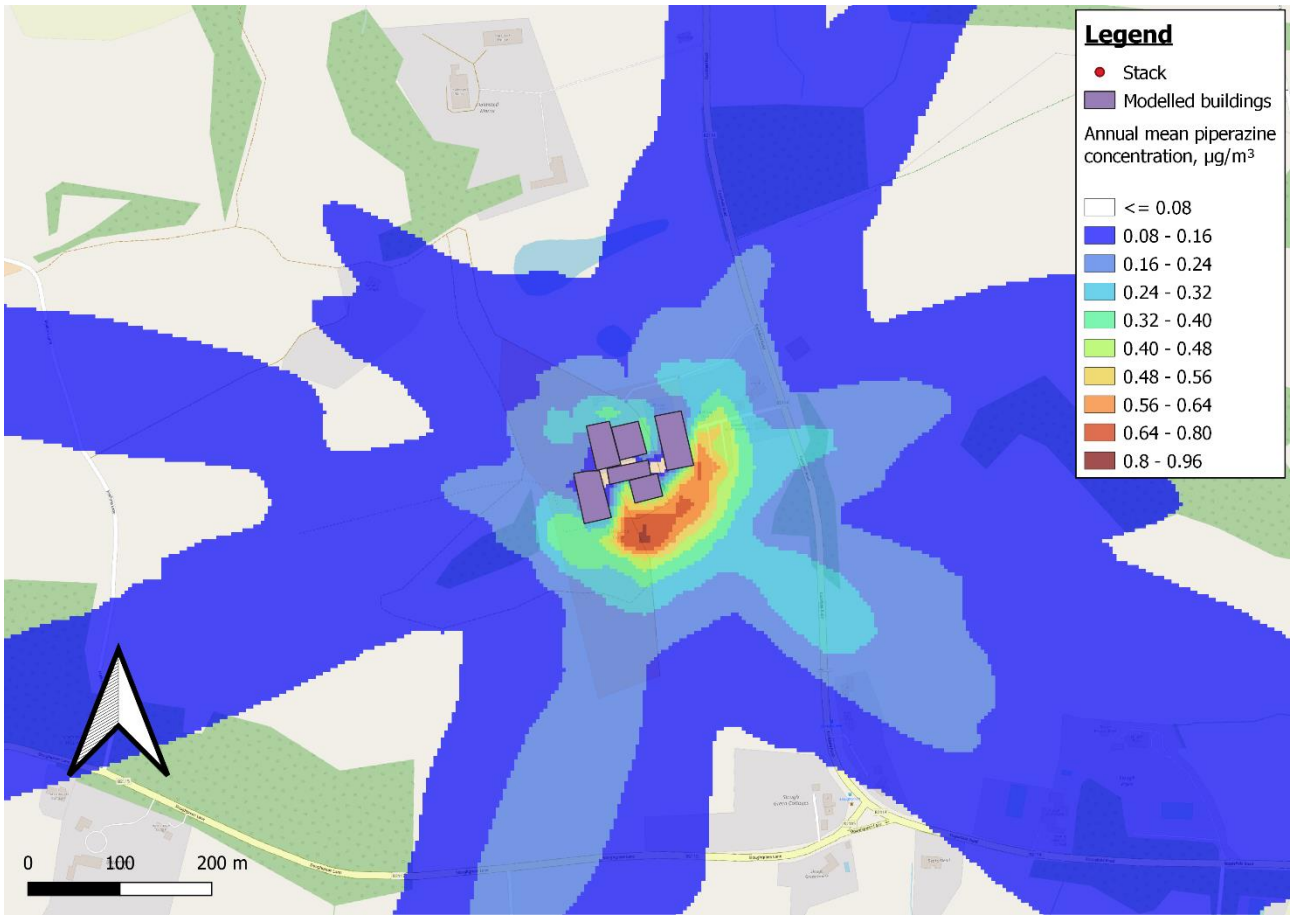
ID	Receptor Location	No FGR		35% FGR		Impact descriptor
		PC & PEC (µg/m^3)	PC & PEC as % of EAL	PC & PEC (µg/m^3)	PC & PEC as % of EAL	
R39	Barnsnape Lodge	0.21	0.70%	0.24	0.78%	Screened out
R40	Paternosters Cottage	0.20	0.67%	0.22	0.74%	Screened out
R41	Deaks	0.01	0.02%	0.01	0.02%	Screened out

Table A1-10: Maximum predicted PCs to 8-hour mean piperazine concentrations between 2015 and 2019, and comparison against the indicative EAL for piperazine

ID	Receptor Location	No FGR		35% FGR		Impact descriptor
		PC (µg/m^3)	PC as % of EAL	PC (µg/m^3)	PC as % of EAL	
-	Maximum across grid	0.74	74%	0.96	96%	Substantial
R1	Cuckfield Road 4	0.11	11%	0.13	13%	Slight
R2	Cuckfield Road 2	0.07	7%	0.08	8%	Screened out
R3	Cuckfield Road 22	0.12	12%	0.13	13%	Slight
R4	Slough Place Farm	0.28	28%	0.34	34%	Moderate
R5	Holmstead Farm	0.24	24%	0.27	27%	Moderate
R6	Holmstead Farm	0.22	22%	0.24	24%	Moderate
R7	Holmstead Farm	0.20	20%	0.22	22%	Moderate
R8	Hollyhus	0.04	4%	0.04	4%	Screened out
R9	Holmsted Manor	0.04	4%	0.04	4%	Screened out
R10	Holmsted Manor 2	0.02	2%	0.03	3%	Screened out
R11	The Coach House	0.04	4%	0.05	5%	Screened out
R12	Mallion's Farm	0.06	6%	0.07	7%	Screened out
R13	Slough Green Cottage	0.09	9%	0.12	12%	Slight
R14	Slough Place Cottage	0.06	6%	0.06	6%	Screened out
R15	Cleavers Barn	0.06	6%	0.06	6%	Screened out
R16	Cleavers Cottage	0.04	4%	0.05	5%	Screened out
R17	Mizbrooks House	0.01	1%	0.02	2%	Screened out
R18	Winscot	0.01	1%	0.02	2%	Screened out
R19	Oakfield House	0.09	9%	0.11	11%	Slight
R20	Moorfields Farm Cott	0.09	9%	0.11	11%	Slight
R21	Moorfields Farmhouse	0.08	8%	0.10	10%	Screened out
R22	Moorfields	0.08	8%	0.10	10%	Screened out
R23	Fowlers	0.04	4%	0.04	4%	Screened out
R24	Spencer Barn	0.04	4%	0.04	4%	Screened out
R25	Barsnape Farm	0.04	4%	0.05	5%	Screened out
R26	Broxmead Farm	0.02	2%	0.03	3%	Screened out
R27	Oak Wood House	0.03	3%	0.03	3%	Screened out
R28	Great Thorndean Farm	0.03	3%	0.04	4%	Screened out
R29	Little Domick	0.02	2%	0.03	3%	Screened out
R30	Wych Cottage	0.04	4%	0.05	5%	Screened out
R31	Bigges Farm 1	0.01	1%	0.02	2%	Screened out

ID	Receptor Location	No FGR		35% FGR		Impact descriptor
		PC (µg/m^3)	PC as % of EAL	PC (µg/m^3)	PC as % of EAL	
R32	The Forge	0.02	2%	0.02	2%	Screened out
R33	Red House	0.02	2%	0.03	3%	Screened out
R34	Amberstone	0.05	5%	0.06	6%	Screened out
R35	Slough Green House	0.06	6%	0.07	7%	Screened out
R36	Deaks Mead	0.05	5%	0.06	6%	Screened out
R37	Hazelbrook Farm	0.03	3%	0.04	4%	Screened out
R38	Barsnape Lodge	0.03	3%	0.04	4%	Screened out
R39	Barnsnape Lodge	0.05	5%	0.07	7%	Screened out
R40	Paternosters Cottage	0.08	8%	0.08	8%	Screened out
R41	Deaks	0.00	0%	0.00	0%	Screened out

Figure A1-2: Maximum modelled 8-hour mean piperazine concentration as % of the indicative EAL in the 35% FGR scenario, worst-case year



N-amine concentrations

Table A1.11 presents the maximum predicted PECs for total annual mean N-amine concentrations (comprising both nitramines and nitrosamines) when amine emissions from the Facility are modelled as MEA. Results are presented for both the expected 35% FGR operational scenario, and the worst-case operational scenario with no FGR. Results are provided at nearby residential receptors, in addition to the maximum across the entire

modelled grid. As background concentrations for these pollutants are assumed to be negligible, the PCs and PECs are equal.

Figure A1-3 illustrates the predicted PECs for the worst-case meteorological year as a heat map. The maximum PEC from the Facility is predicted to occur immediately to the east of the stack, within the Holmsted Farm site and does not represent a relevant location for long-term exposure.

As the maximum PEC is less than 50% of the EAL at all locations, the site impacts for annual mean nitramine and nitrosamine concentrations can be screened out as 'insignificant'.

Table A1.11: Maximum predicted PECs to annual mean N-amine concentrations between 2015 and 2019, with comparison against the EAL for NDMA, amine emissions modelled as MEA

ID	Receptor Location	No FGR		35% FGR		Impact descriptor
		PC & PEC N-amine annual mean ($ng.m^{-3}$)	PC & PEC as % of MEA EAL (0.2 $ng.m^{-3}$)	PC & PEC N-amine annual mean ($ng.m^{-3}$)	PC & PEC as % of NDMA EAL (0.2 $ng.m^{-3}$)	
-	Maximum across grid	0.084	42.1%	0.108	54.1%	Negligible
R1	Cuckfield Road 4	0.002	1.1%	0.003	1.4%	Negligible
R2	Cuckfield Road 2	0.002	0.8%	0.002	0.9%	Negligible
R3	Cuckfield Road 22	0.002	0.9%	0.002	1.2%	Negligible
R4	Slough Place Farm	0.036	17.9%	0.040	19.8%	Negligible
R5	Holmstead Farm	0.031	15.6%	0.034	16.9%	Negligible
R6	Holmstead Farm	0.025	12.4%	0.027	13.3%	Negligible
R7	Holmstead Farm	0.026	13.1%	0.028	14.0%	Negligible
R8	Hollyhus	0.001	0.5%	0.001	0.6%	Negligible
R9	Holmsted Manor	0.001	0.3%	0.001	0.4%	Negligible
R10	Holmsted Manor 2	0.001	0.3%	0.001	0.3%	Negligible
R11	The Coach House	0.000	0.2%	0.000	0.2%	Negligible
R12	Mallion's Farm	0.001	0.6%	0.001	0.7%	Negligible
R13	Slough Green Cottage	0.002	1.0%	0.003	1.3%	Negligible
R14	Slough Place Cottage	0.002	1.0%	0.002	1.2%	Negligible
R15	Cleavers Barn	0.002	1.1%	0.002	1.2%	Negligible
R16	Cleavers Cottage	0.001	0.5%	0.001	0.6%	Negligible
R17	Mizbrooks House	0.000	0.1%	0.000	0.2%	Negligible
R18	Winscot	0.000	0.1%	0.000	0.2%	Negligible
R19	Oakfield House	0.001	0.7%	0.002	0.8%	Negligible
R20	Moorfields Farm Cott	0.001	0.6%	0.001	0.7%	Negligible
R21	Moorfields Farmhouse	0.001	0.6%	0.001	0.7%	Negligible
R22	Moorfields	0.001	0.6%	0.001	0.7%	Negligible
R23	Fowlers	0.001	0.3%	0.001	0.4%	Negligible
R24	Spencer Barn	0.001	0.3%	0.001	0.4%	Negligible
R25	Barsnape Farm	0.001	0.3%	0.001	0.4%	Negligible
R26	Broxmead Farm	0.000	0.2%	0.000	0.2%	Negligible
R27	Oak Wood House	0.000	0.2%	0.000	0.2%	Negligible
R28	Great Thorndean Farm	0.000	0.1%	0.000	0.1%	Negligible
R29	Little Domick	0.000	0.1%	0.000	0.2%	Negligible
R30	Wych Cottage	0.001	0.7%	0.002	0.9%	Negligible
R31	Bigges Farm 1	0.000	0.1%	0.000	0.1%	Negligible

ID	Receptor Location	No FGR		35% FGR		Impact descriptor
		PC & PEC N-amine annual mean (ng.m^{-3})	PC & PEC as % of MEA EAL (0.2 ng.m^{-3})	PC & PEC N-amine annual mean (ng.m^{-3})	PC & PEC as % of NDMA EAL (0.2 ng.m^{-3})	
R32	The Forge	0.000	0.1%	0.000	0.1%	Negligible
R33	Red House (Staplefield)	0.000	0.1%	0.000	0.1%	Negligible
R34	Amberstone	0.001	0.5%	0.001	0.5%	Negligible
R35	Slough Green House	0.001	0.6%	0.001	0.7%	Negligible
R36	Deaks Mead	0.001	0.4%	0.001	0.5%	Negligible
R37	Hazelbrook Farm	0.001	0.4%	0.001	0.4%	Negligible
R38	Barsnape Lodge	0.001	0.5%	0.001	0.5%	Negligible
R39	Barnsnape Lodge	0.001	0.4%	0.001	0.4%	Negligible
R40	Paternosters Cottage	0.001	0.6%	0.002	0.8%	Negligible
R41	Deaks	0.000	0.2%	0.000	0.2%	Negligible

Figure A1-3: Maximum modelled annual mean N-amine concentration as % of the NDMA EAL in the 35% FGR scenario, worst-case year, modelled as MEA

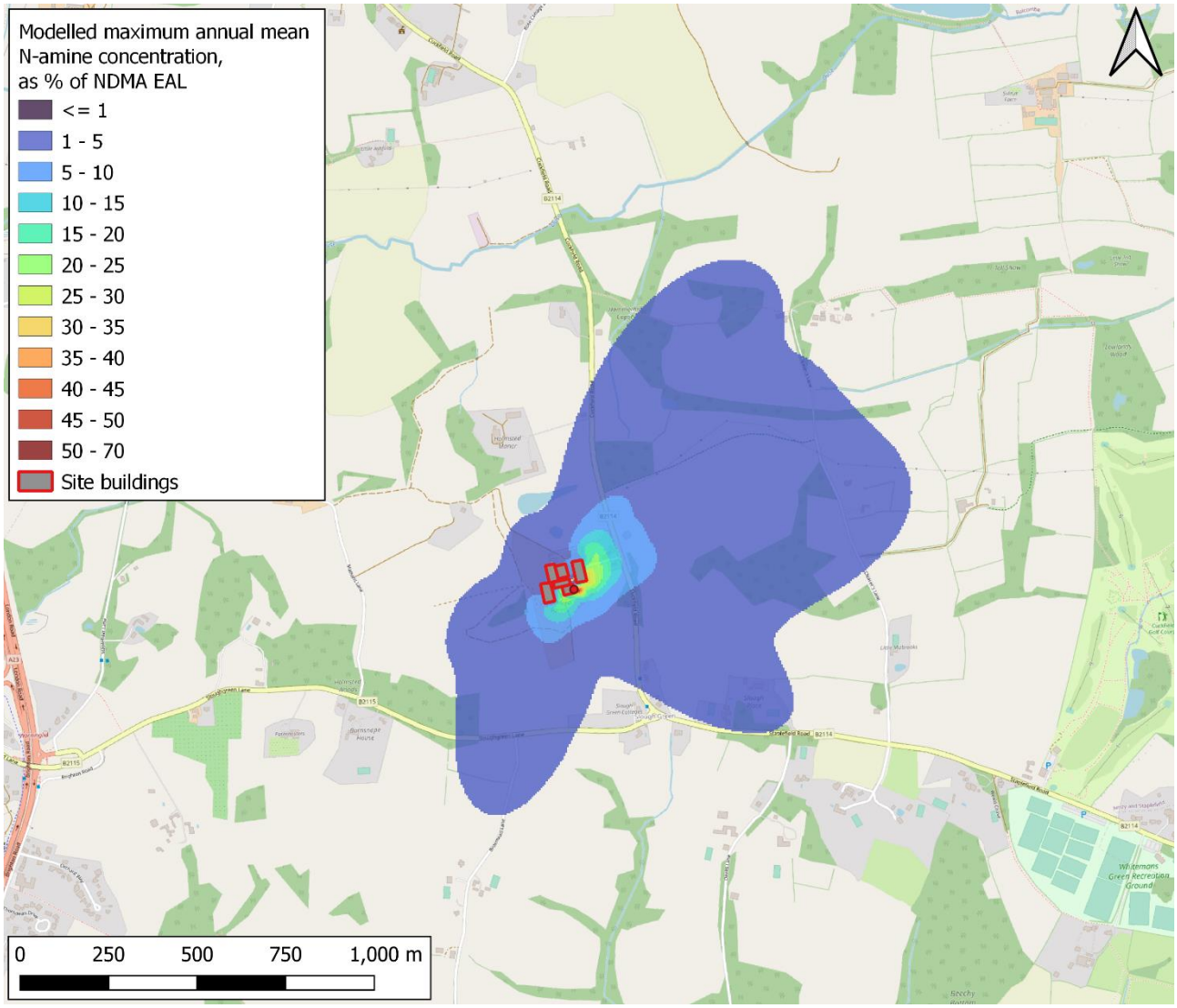


Table A1.12 presents the maximum predicted PECs for total annual mean N-amine concentrations (comprising both nitramines and nitrosamines) when amine emissions from the Facility are modelled as DMA. Results are presented for both the expected 35% FGR operational scenario, and the worst-case operational scenario with no FGR. Results are provided at nearby residential receptors, in addition to the maximum across the entire modelled grid.

Figure A1-4 illustrates the predicted PECs for the worst-case meteorological year in the 35% FGR scenario as a heat map. As for the MEA case, the maximum PEC from the Facility is predicted to occur immediately to the east of the stack, within the Holmsted Farm site and does not represent a relevant location for long-term exposure.

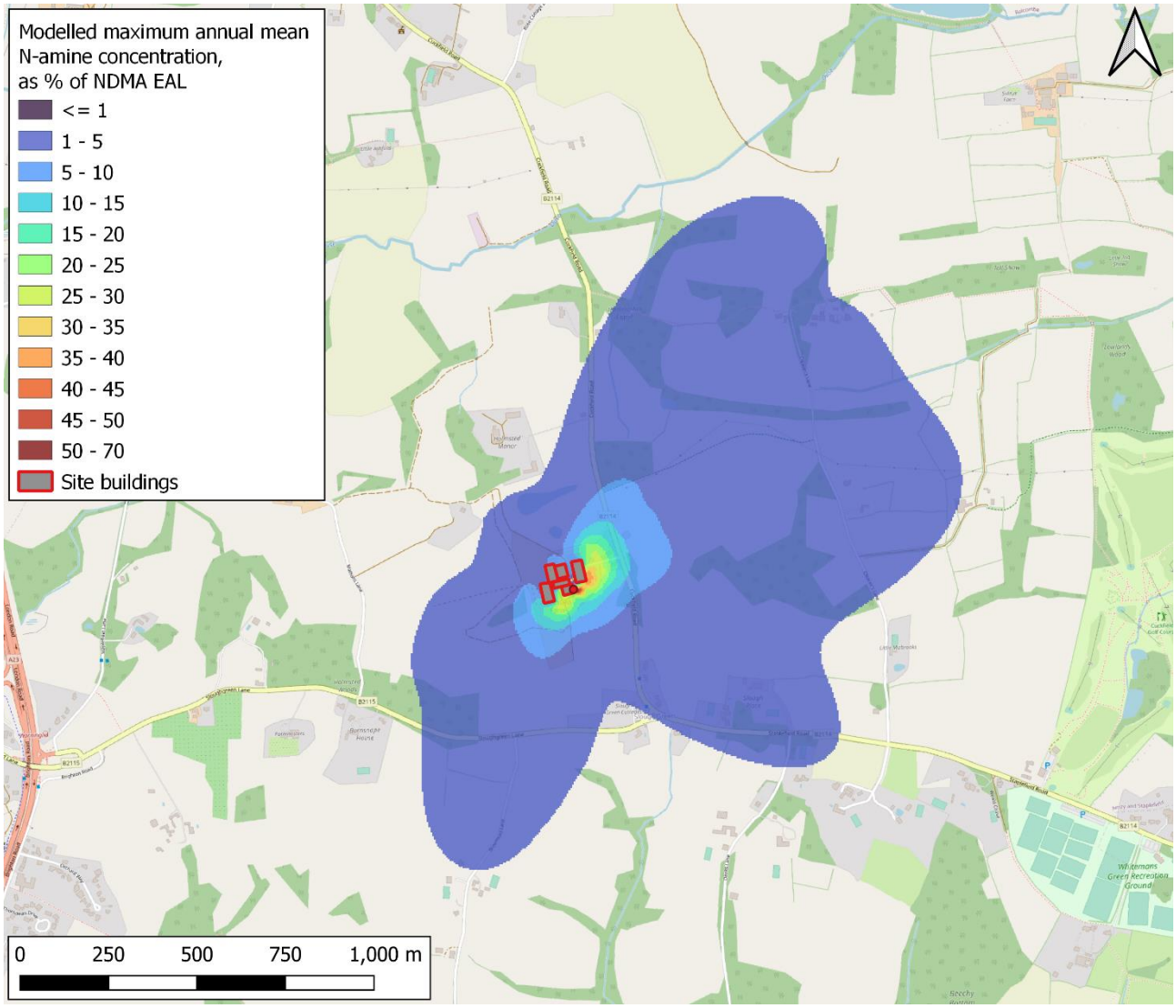
As the maximum PEC is less than 70% of the EAL at all locations for both modelled scenarios, the site impacts for annual mean nitramine and nitrosamine concentrations can be screened out as ‘insignificant’.

Table A1.12: Maximum predicted PECs to annual mean N-amine concentrations between 2015 and 2019, with comparison against the EAL for NDMA, amine emissions modelled as DMA

ID	Receptor Location	No FGR		35% FGR		Impact descriptor
		PC & PEC N-amine annual mean (ng/m^3)	PEC as % of MEA EAL (0.2 $ng.m^{-3}$)	PC & PEC N-amine annual mean ($ng.m^3$)	PEC as % of NDMA EAL (0.2 $ng.m^{-3}$)	
-	Maximum across grid	0.088	43.9%	0.116	58.2%	Negligible
R1	Cuckfield Road 4	0.003	1.5%	0.004	1.8%	Negligible
R2	Cuckfield Road 2	0.002	1.1%	0.003	1.3%	Negligible
R3	Cuckfield Road 22	0.002	1.2%	0.003	1.4%	Negligible
R4	Slough Place Farm	0.046	22.9%	0.051	25.3%	Negligible
R5	Holmstead Farm	0.042	20.9%	0.045	22.5%	Negligible
R6	Holmstead Farm	0.032	16.2%	0.034	17.2%	Negligible
R7	Holmstead Farm	0.035	17.5%	0.037	18.5%	Negligible
R8	Hollyhus	0.002	0.8%	0.002	0.8%	Negligible
R9	Holmsted Manor	0.001	0.5%	0.001	0.5%	Negligible
R10	Holmsted Manor 2	0.001	0.5%	0.001	0.5%	Negligible
R11	The Coach House	0.000	0.2%	0.001	0.3%	Negligible
R12	Mallion's Farm	0.002	0.9%	0.002	1.0%	Negligible
R13	Slough Green Cottage	0.003	1.3%	0.003	1.6%	Negligible
R14	Slough Place Cottage	0.002	1.2%	0.003	1.4%	Negligible
R15	Cleavers Barn	0.003	1.3%	0.003	1.4%	Negligible
R16	Cleavers Cottage	0.001	0.6%	0.002	0.8%	Negligible
R17	Mizbrooks House	0.000	0.2%	0.001	0.3%	Negligible
R18	Winscot	0.000	0.2%	0.001	0.3%	Negligible
R19	Oakfield House	0.002	0.9%	0.002	1.0%	Negligible
R20	Moorfields Farm Cott	0.002	0.8%	0.002	1.0%	Negligible
R21	Moorfields Farmhouse	0.002	0.8%	0.002	0.9%	Negligible
R22	Moorfields	0.001	0.7%	0.002	0.9%	Negligible
R23	Fowlers	0.001	0.4%	0.001	0.5%	Negligible
R24	Spencer Barn	0.001	0.4%	0.001	0.5%	Negligible
R25	Barsnape Farm	0.001	0.4%	0.001	0.5%	Negligible
R26	Broxmead Farm	0.001	0.3%	0.001	0.3%	Negligible
R27	Oak Wood House	0.001	0.3%	0.001	0.3%	Negligible
R28	Great Thorndean Farm	0.000	0.2%	0.000	0.2%	Negligible
R29	Little Domick	0.000	0.2%	0.000	0.2%	Negligible
R30	Wych Cottage	0.002	0.9%	0.002	1.1%	Negligible
R31	Bigges Farm 1	0.000	0.1%	0.000	0.2%	Negligible
R32	The Forge	0.000	0.1%	0.000	0.2%	Negligible
R33	Red House	0.000	0.1%	0.000	0.1%	Negligible
R34	Amberstone	0.001	0.7%	0.001	0.7%	Negligible
R35	Slough Green House	0.002	0.8%	0.002	1.0%	Negligible
R36	Deaks Mead	0.001	0.5%	0.001	0.6%	Negligible
R37	Hazelbrook Farm	0.001	0.6%	0.001	0.6%	Negligible

ID	Receptor Location	No FGR		35% FGR		Impact descriptor
		PC & PEC N-amine annual mean (ng/m^3)	PEC as % of MEA EAL (0.2 ng.m^{-3})	PC & PEC N-amine annual mean (ng.m^3)	PEC as % of NDMA EAL (0.2 ng.m^{-3})	
R38	Barsnape Lodge	0.001	0.7%	0.001	0.7%	Negligible
R39	Barnsnape Lodge	0.001	0.6%	0.001	0.6%	Negligible
R40	Paternosters Cottage	0.002	0.8%	0.002	0.9%	Negligible
R41	Deaks	0.000	0.2%	0.001	0.3%	Negligible

Figure A1-4: Maximum modelled annual mean N-amine concentration as % of the NDMA EAL in the 35% FGR scenario, worst-case year, modelled as DMA



Sensitivity analysis

The results presented above indicate that modelling the release as DMA is the more conservative assumption. However, even with this worst-case assumption, the maximum PEC is less than 70% of the EAL for NDMA, so the site impacts for annual mean nitramine and nitrosamine concentrations can be screened out as 'insignificant'.

Table A1.13 presents the results of using hourly background NOx and NO_2 data from the roadside Storrington site for 2018, the year of maximum predicted PCs. Note that O_3 concentrations from the Lullington Heath site were used, as O_3 is not monitored at the Storrington site.

Use of background data from the Storrington site slightly reduces predicted N-amine concentrations, indicating that the Lullington Heath site used in the main study provides a worst-case assessment.

Table A1.13: Maximum predicted PCs to modelled N-amine concentrations using background concentrations from the Storrington AURN site, compared with the Lullington Heath site used in the main study, ng/m³

Solvent	Original (Lullington Heath)	Storrington background
DMA	0.118	0.120
MEA	0.097	0.098

CONCLUSION

The results of dispersion modelling indicate that Predicted Environmental Concentrations of all amines and amine degradation products will not exceed the EALs and derived EALs at relevant receptors.

Appendix 2 - Sensitivity Analysis

Table A2.1 presents the maximum process contributions across the grid for the five years of meteorological data.

Table A2.1: Meteorological data sensitivity of Maximum Process Contributions (µg/m^3) Across Grid

Pollutant	Averaging Period	2015	2016	2017	2018	2019
Benzene	Annual mean	**1.31**	1.23	1.27	1.29	1.21
Carbon Monoxide	Maximum daily running 8 hour mean	0.11	0.08	0.08	0.11	0.08
Nitrogen dioxide	Annual mean	**27.44**	25.62	26.64	27.04	25.20
Nitrogen dioxide	1-hour mean (99.79th percentile)	65.22	66.60	73.60	**74.53**	67.55
Particles	24-hour mean (90.41 percentile)	6.92	6.86	6.94	**6.94**	6.69
Particles	Annual mean	**4.07**	3.80	3.95	4.01	3.74
Hydrogen Cyanide	1 hour mean (maximum)	2.83	**3.16**	2.95	2.79	2.96
Formaldehyde	30-minute mean (maximum)	2.99	**3.21**	3.00	2.82	2.98
Formaldehyde	Annual mean	**0.394**	0.368	0.382	0.388	0.362
Ammonia	Annual mean	**0.131**	0.123	0.127	0.129	0.121
Ammonia	1 hour mean (maximum)	0.94	**1.05**	0.98	0.93	0.99
Acetaldehyde	Annual mean	**0.263**	0.25	0.25	0.259	0.24
Acetaldehyde	1 hour mean (maximum)	1.89	**2.11**	1.97	1.86	1.97
MEA	1 hour mean (maximum)	6.60	7.38	6.89	6.52	6.90
MEA	24 hour mean (maximum)	2.45	2.48	2.34	2.91	2.34
NDMA	Annual mean	0.129	0.123	0.128	0.129	0.122

Note: **Bold** – Maximum PC

Table A2.1 shows that the highest PC are predicted typically for the year 2015, as such modelled results reported are based on the year 2015.

Table A2.2 presents the results of sensitivity testing into the use of the complex terrain option in ADMS 5, changes to the dispersion site surface roughness, and flowrate using meteorological data for 2015.

Table A2.2: Sensitivity test of terrain, surface roughness and flowrate (2015 meteorological data) - Maximum Process Contributions (µg/m^3) Across Grid

Pollutant	Averaging Period	Original	Terrain	0.3sr	0.1sr	Flowrate
Benzene	Annual mean	1.31	1.30	**1.34**	1.24	1.08
Carbon Monoxide	Maximum daily running 8 hour mean	0.11	0.10	0.11	0.10	0.08
Nitrogen dioxide	Annual mean	27.44	27.25	**28.10**	25.85	20.85
Nitrogen dioxide	1-hour mean (99.79th percentile)	**65.22**	63.60	65.05	61.41	55.29
Particles	24-hour mean (90.41 percentile)	6.92	6.76	**7.07**	6.28	4.95
Particles	Annual mean	4.07	4.04	**4.17**	3.83	3.13
Hydrogen Cyanide	1 hour mean (maximum)	2.83	2.73	**2.85**	2.57	2.60
Formaldehyde	30-minute mean (maximum)	**2.99**	2.76	2.89	2.61	2.62
Formaldehyde	Annual mean	0.39	0.39	**0.40**	0.37	0.29
Ammonia	Annual mean	0.13	0.13	**0.13**	0.12	0.10
Ammonia	1 hour mean (maximum)	0.94	0.91	**0.95**	0.86	0.87
Acetaldehyde	Annual mean	0.26	0.26	**0.27**	0.25	0.20
Acetaldehyde	1 hour mean (maximum)	1.89	1.82	**1.90**	1.71	1.73

Note: **Bold** – Maximum PC

Typically, the 0.3 surface roughness results in a higher concentration (no more than 3% higher l) compared to the original which is based on a 0.2 m surface roughness (representative of agricultural area min) used in the original model. However, this would not change the outcome of the assessment.

The effects of terrain, 0.1 m surface roughness (representative of root crops) and flow rate would result in much lower predicted concentrations compared to the original assessment.

It is concluded that although slightly higher concentrations are predicted with 0.3 surface roughness this is not expected to change the outcome of the assessment. Furthermore, the surface roughness of 0.3 (applicable to agricultural area max) is not quite appropriate for the study area which is mostly low-lying agricultural land and open grassland.

Appendix 3 – Modelled Results

Tables A3.1 to Table A3.3 presents the PEC at the nearby human receptors for the pollutants with a minor to moderate impact.

Table A3.1: Predicted Environmental Contributions (µg/m^3) of Benzene at Nearby Human Receptors

ID	Receptor Location	PC Benzene Annual mean (µg/m^3)	PC as % of AQO	PEC as % of AQO	Impact descriptor
R1	Cuckfield Road 4	0.02	0.40%	14.96%	Screened out <1%
R2	Cuckfield Road 2	0.02	0.33%	14.89%	Screened out <1%
R3	Cuckfield Road 22	0.01	0.25%	14.81%	Screened out <1%
R4	Slough Place Farm	0.01	0.29%	14.85%	Screened out <1%
R5	Holmstead Farm 1	0.29	5.79%	20.35%	Minor
R6	Holmstead Farm Bunga	0.28	5.67%	20.23%	Minor
R7	Holmstead Farm Bunga	0.22	4.41%	18.97%	Minor
R8	Hollyhus	0.24	4.71%	19.27%	Minor
R9	Holmsted Manor 1	0.01	0.23%	14.79%	Screened out <1%
R10	Holmsted Manor 2	0.01	0.15%	14.71%	Screened out <1%
R11	The Coach House	0.01	0.13%	14.69%	Screened out <1%
R12	Mallion's Farm	0.00	0.07%	14.63%	Screened out <1%
R13	Slough Green Cottage	0.01	0.18%	14.74%	Screened out <1%
R14	Slough Place Cottage	0.02	0.35%	14.91%	Screened out <1%
R15	Cleavers Barn	0.02	0.37%	14.93%	Screened out <1%
R16	Cleavers Cottage	0.02	0.40%	14.96%	Screened out <1%
R17	Mizbrooks House	0.01	0.19%	14.75%	Screened out <1%
R18	Winscot	0.00	0.06%	14.62%	Screened out <1%
R19	Oakfield House	0.00	0.06%	14.62%	Screened out <1%
R20	Moorfields Farm Cott	0.02	0.35%	14.91%	Screened out <1%
R21	Moorfields Farmhouse	0.02	0.34%	14.90%	Screened out <1%
R22	Moorfields	0.02	0.33%	14.89%	Screened out <1%
R23	Fowlers	0.01	0.30%	14.86%	Screened out <1%
R24	Spencer Barn	0.01	0.16%	14.72%	Screened out <1%
R25	Barsnape Farm	0.01	0.16%	14.72%	Screened out <1%
R26	Broxmead Farm	0.01	0.15%	14.71%	Screened out <1%
R27	Oak Wood House	0.00	0.09%	14.65%	Screened out <1%
R28	Great Thorndean Farm	0.00	0.09%	14.65%	Screened out <1%
R29	Little Domick	0.00	0.06%	14.62%	Screened out <1%
R30	Wych Cottage	0.00	0.07%	14.63%	Screened out <1%

ID	Receptor Location	PC Benzene Annual mean (µg/m^3)	PC as % of AQO	PEC as % of AQO	Impact descriptor
R31	Bigges Farm 1	0.02	0.32%	14.88%	Screened out <1%
R32	The Forge	0.00	0.04%	14.60%	Screened out <1%
R33	Red House (Staplefield)	0.00	0.05%	14.61%	Screened out <1%
R34	Amberstone	0.00	0.04%	14.60%	Screened out <1%
R35	Slough Green House	0.01	0.14%	14.70%	Screened out <1%
R36	Deaks Mead	0.01	0.21%	14.77%	Screened out <1%
R37	Hazelbrook Farm	0.01	0.19%	14.75%	Screened out <1%
R38	Barsnape Lodge	0.01	0.18%	14.74%	Screened out <1%
R39	Barnsnape Lodge	0.01	0.21%	14.77%	Screened out <1%
R40	Paternosters Cottage	0.01	0.18%	14.74%	Screened out <1%
R41	Deaks	0.01	0.18%	14.74%	Screened out <1%

Table A3.2: Predicted Environmental Contributions (µg/m^3) of NO2 Annual mean at Nearby Human Receptors

ID	Receptor Location	PC NO2 Annual mean (µg/m^3)	PC as % of AQO	PEC as % of AQO	Impact descriptor
R1	Cuckfield Road 4	0.42	1.04%	22.29%	Negligible
R2	Cuckfield Road 2	0.35	0.87%	22.12%	Screened out <1%
R3	Cuckfield Road 22	0.26	0.64%	21.89%	Screened out <1%
R4	Slough Place Farm	0.30	0.75%	22.00%	Screened out <1%
R5	Holmstead Farm 1	6.05	15.13%	36.38%	Moderate
R6	Holmstead Farm Bunga	5.92	14.81%	36.06%	Moderate
R7	Holmstead Farm Bunga	4.61	11.51%	32.76%	Minor
R8	Hollyhus	4.93	12.31%	33.56%	Minor
R9	Holmsted Manor 1	0.24	0.59%	21.84%	Screened out <1%
R10	Holmsted Manor 2	0.15	0.38%	21.63%	Screened out <1%
R11	The Coach House	0.14	0.35%	21.60%	Screened out <1%
R12	Mallion's Farm	0.08	0.20%	21.45%	Screened out <1%
R13	Slough Green Cottage	0.19	0.48%	21.73%	Screened out <1%
R14	Slough Place Cottage	0.36	0.91%	22.16%	Screened out <1%
R15	Cleavers Barn	0.39	0.97%	22.22%	Screened out <1%
R16	Cleavers Cottage	0.42	1.06%	22.31%	Negligible
R17	Mizbrooks House	0.19	0.49%	21.74%	Screened out <1%
R18	Winscot	0.06	0.16%	21.41%	Screened out <1%

ID	Receptor Location	PC NO2 Annual mean (µg/m^3)	PC as % of AQO	PEC as % of AQO	Impact descriptor
R19	Oakfield House	0.06	0.15%	21.40%	Screened out <1%
R20	Moorfields Farm Cott	0.37	0.92%	22.17%	Screened out <1%
R21	Moorfields Farmhouse	0.35	0.88%	22.13%	Screened out <1%
R22	Moorfields	0.34	0.85%	22.10%	Screened out <1%
R23	Fowlers	0.31	0.78%	22.03%	Screened out <1%
R24	Spencer Barn	0.17	0.42%	21.67%	Screened out <1%
R25	Barsnape Farm	0.17	0.42%	21.67%	Screened out <1%
R26	Broxmead Farm	0.15	0.38%	21.63%	Screened out <1%
R27	Oak Wood House	0.10	0.24%	21.49%	Screened out <1%
R28	Great Thorndean Farm	0.09	0.23%	21.48%	Screened out <1%
R29	Little Domick	0.06	0.15%	21.40%	Screened out <1%
R30	Wych Cottage	0.07	0.18%	21.43%	Screened out <1%
R31	Bigges Farm 1	0.33	0.83%	22.08%	Screened out <1%
R32	The Forge	0.05	0.11%	21.36%	Screened out <1%
R33	Red House (Staplefield)	0.05	0.13%	21.38%	Screened out <1%
R34	Amberstone	0.04	0.10%	21.35%	Screened out <1%
R35	Slough Green House	0.15	0.38%	21.63%	Screened out <1%
R36	Deaks Mead	0.21	0.54%	21.79%	Screened out <1%
R37	Hazelbrook Farm	0.20	0.50%	21.75%	Screened out <1%
R38	Barsnape Lodge	0.19	0.47%	21.72%	Screened out <1%
R39	Barnsnape Lodge	0.22	0.56%	21.81%	Screened out <1%
R40	Paternosters Cottage	0.19	0.47%	21.72%	Screened out <1%
R41	Deaks	0.19	0.48%	21.73%	Screened out <1%

Table A3.3: Predicted Environmental Contributions (µg/m^3) of NO_2 1 hour mean at Nearby Human Receptors

ID	Receptor Location	PC NO2 1-hour mean (99.79th percentile) (µg/m^3)	PC as % of AQO	PEC as % of AQO	Impact descriptor
R1	Cuckfield Road 4	15.72	7.86%	16.36%	Screened out <10%
R2	Cuckfield Road 2	13.00	6.50%	15.00%	Screened out <10%
R3	Cuckfield Road 22	10.94	5.47%	13.97%	Screened out <10%
R4	Slough Place Farm	12.75	6.38%	14.88%	Screened out <10%
R5	Holmstead Farm 1	27.76	13.88%	22.38%	Moderate
R6	Holmstead Farm Bunga	24.57	12.29%	20.79%	Moderate

ID	Receptor Location	PC NO2 1-hour mean (99.79th percentile) (µg/m^3)	PC as % of AQO	PEC as % of AQO	Impact descriptor
R7	Holmstead Farm Bunga	25.23	12.62%	21.12%	Moderate
R8	Hollyhus	21.72	10.86%	19.36%	Moderate
R9	Holmsted Manor 1	5.47	2.73%	11.23%	Screened out <10%
R10	Holmsted Manor 2	3.78	1.89%	10.39%	Screened out <10%
R11	The Coach House	3.34	1.67%	10.17%	Screened out <10%
R12	Mallion's Farm	4.14	2.07%	10.57%	Screened out <10%
R13	Slough Green Cottage	5.55	2.78%	11.28%	Screened out <10%
R14	Slough Place Cottage	13.49	6.75%	15.25%	Screened out <10%
R15	Cleavers Barn	7.15	3.58%	12.08%	Screened out <10%
R16	Cleavers Cottage	7.83	3.91%	12.41%	Screened out <10%
R17	Mizbrooks House	6.29	3.14%	11.64%	Screened out <10%
R18	Winscot	2.10	1.05%	9.55%	Screened out <10%
R19	Oakfield House	1.73	0.87%	9.37%	Screened out <10%
R20	Moorfields Farm Cott	8.62	4.31%	12.81%	Screened out <10%
R21	Moorfields Farmhouse	8.34	4.17%	12.67%	Screened out <10%
R22	Moorfields	8.26	4.13%	12.63%	Screened out <10%
R23	Fowlers	7.28	3.64%	12.14%	Screened out <10%
R24	Spencer Barn	4.58	2.29%	10.79%	Screened out <10%
R25	Barsnape Farm	4.64	2.32%	10.82%	Screened out <10%
R26	Broxmead Farm	3.71	1.86%	10.36%	Screened out <10%
R27	Oak Wood House	2.80	1.40%	9.90%	Screened out <10%
R28	Great Thorndean Farm	3.44	1.72%	10.22%	Screened out <10%
R29	Little Domick	2.50	1.25%	9.75%	Screened out <10%
R30	Wych Cottage	2.52	1.26%	9.76%	Screened out <10%
R31	Bigges Farm 1	4.53	2.26%	10.76%	Screened out <10%
R32	The Forge	1.59	0.80%	9.30%	Screened out <10%
R33	Red House (Staplefield)	2.40	1.20%	9.70%	Screened out <10%
R34	Amberstone	1.90	0.95%	9.45%	Screened out <10%
R35	Slough Green House	4.34	2.17%	10.67%	Screened out <10%
R36	Deaks Mead	9.42	4.71%	13.21%	Screened out <10%
R37	Hazelbrook Farm	5.12	2.56%	11.06%	Screened out <10%
R38	Barsnape Lodge	3.90	1.95%	10.45%	Screened out <10%
R39	Barnsnape Lodge	4.05	2.02%	10.52%	Screened out <10%
R40	Paternosters Cottage	5.43	2.71%	11.21%	Screened out <10%
R41	Deaks	8.04	4.02%	12.52%	Screened out <10%

The results show that a minor to moderate impact of annual mean benzene and NO_2; and hourly mean NO_2 is predicted only at four receptors (R4 to R8). However, the predicted environmental concentration at these receptors is well below the AQO and EAL (less than 70%).

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